The Uptake and Utility of Seasonal Forecasting Products for Commercial Maize Farmers in South Africa

Submitted by

Peter Johnston

Thesis presented for the degree of Doctor of Philosophy
In the Department of Environmental and Geographical Science
University of Cape Town

February 2008

Abstract

The development of seasonal climate forecasts with significant scientific skill has led to their uptake, utility and application in various sectors, but economic and social benefits are not assured outcomes of forecast dissemination. This research aimed to determine, assess and analyse the uptake, use and application of seasonal forecasts amongst commercial maize farmers, and to determine the role that forecasts played in their management decision-making processes. Two assertions regarding the usefulness were made, namely that seasonal forecasts in South Africa were *not* generally used amongst maize farmers and that even if they were received, it was unlikely that they would be beneficial in their current form; and secondly, that they were only likely to be beneficial when they were more accurate, more focused, more specific and better disseminated than at present.

A major source of food security, South African commercial maize farmers are subject to highly variable climate and market conditions. The current and potential impact of existing and future forecast products in this sector remains uncertain. This thesis focused on 3 distinct aspects; the format, dissemination and uptake of forecasts; the validity or usefulness of forecasts; and the dynamics of farmers' decision-making. Maize farmers were targeted and surveyed to determine their use of forecasts. A study group was selected and monthly forecasts were issued for four growing seasons. Interviews and surveys were conducted at regular intervals and the forecast format adjusted accordingly. The gathered information provides appreciable insight into the usefulness of the forecast, validating both assertions and allowing forecast providers, analysts and distributors the opportunity of continual improvement, adaptation and sector-specific tailoring of information. The development of a user-friendly verification system to assist decision-making added some qualitative value to the forecast by responding to users' needs.

The financial options available to farmers regarding the sale of their products, and the relationship between forecasts and market prices were investigated and found to be uncertain. This work concluded that forecasts require specific and detailed analysis and interpretation before being disseminated and recommended the establishment of crop-, and area-specific forecast advisors to gain maximum benefit to maize farmers.

Table of Contents

List of Figures

List of Tables

List of Boxes

List of Appendices

Acknowledgements

A work of this nature cannot be completed without the advice, support and encouragement of a large number of colleagues, friends and family. I would, therefore, like to thank my supervisor Bruce Hewitson for his guidance, advice and not least, his unflinching confidence that I would be capable of doing this. His wide knowledge, sage advice and thoughtful suggestions were to prove invaluable. I must also thank Bill Easterling, who guided this work into territory that it would not have otherwise have gone, and would have been the worse off for it. The financial support of the former Department of Arts, Culture, Science and Technology (DACST) is formally acknowledged.

Along the way, innumerable people discussed, commented on and debated the nature and uptake of seasonal forecasts – to all these, especially Mark Tadross, Emma Archer, Gina Ziervogel, Emsie Klopper, Sue Walker and Coleen Vogel in SA, Johan van den Berg of Envirovision, David Cobon and his colleagues in Toowoomba, Queensland and those at IRI in New York, thank you for your encouragement, ideas and continuing research on this topic.

This research would not have been possible without the assistance of the maize farmers who were very willing to share their thoughts and perceptions with me. They were all extremely hospitable and helpful. In particular I would like to thank Rhys Rolfe for his friendship, despite his belief that a "queen of the night" cactus was a better predictor of rainfall than any forecast!

To those friends and family who wondered if this would ever be completed, thanks for your encouragement and patience.

Finally to Deborah, Rachael and Phoebe, who bore the brunt of the frustration, time away and stress that a thesis requires, thank you all for your love and support. It would not have been possible without it.

When times are good, be happy; but when times are bad, consider: God has made the one as well as the other.

Ecclesiastes7:14

Chapter 1: Introduction

"I'd say there's a fifty-fifty chance that this season will be wet.."

Maize farmer, Bothaville 2003

1.1 Introduction

The advent of general atmospheric circulation models (GCMs) and the ability to measure and predict sea- surface temperatures (SSTs) has led to the development of seasonal climate forecasts (SCFs) with significant skill. Whereas weather forecasts have rapidly improved to the extent where 7-10 day forecasts are issued with confidence, seasonal forecasts are relatively recent. Specially designed and tested model output generally predicts likelihoods of any rainfall and/or temperature anomalies for a period up to 3-6 months in advance. This has made it possible for scientists, researchers and weather service agencies to issue probabilistic seasonal outlooks for forthcoming seasons in many regions of the world. These outlooks have been applied with varying success to assist with decision-making especially in the rain-fed agricultural sector (Cane and Arkin, 2000; Pagano et al., 2001; Sivakumar, 2006).

Notwithstanding the fact that the scale of the forecasts offers only a broad guide of future conditions for any specific region and that the lead time of the forecast release is indirectly proportional to its accuracy, it has been shown that the forecasts can significantly improve the decision-making of many sectors of society such as transport, water resource management and risk management (Adams et al., 1995; Mjelde et al., 1998; Arndt and Bacou, 2000; Johnston et al., 2007). The issues of temporal and spatial scale are however by no means resolved yet and significant research is underway in order to improve various methods of downscaling (Landman and Tennant, 2000; Wilby and Wigley, 2000). Downscaling adds spatial resolution and skill by incorporating large scale physical variations on the smaller scale pixels of global and regional models.

Inherent in each part of forecast development is a degree of uncertainty. When aggregated, these uncertainties are compounded and this poses a major obstacle to widespread acceptance and application (Farago et al., 1997). As Hoffman (2004) put it "there will always be a high probability of being wrong in forecasting". The generally held belief that an *available* forecast is almost always preferable to the *lack* of a forecast often tends to ignore the uncertain value and skill of forecasts (Joliffe and Stephenson, 2003). The testing of forecasts to assess this skill and value has been encouraged in order to add credence and a realistic appreciation of the benefits and limitations of the forecast.

A concern that has arisen among forecasters and scientists is whether, and how seasonal forecasts are utilised by users and to what extent they are regarded as reliable, valuable and generally worthwhile. A natural consequence of this concern is the exploration of how most social benefit could be obtained from the dissemination of forecast information (Stern and Easterling, 1999). The problem facing users such as farmers is one where, although a product is available and seems beneficial, it remains a little mysterious and inaccessible for their direct application (Broad et al., 2002; Lemos et al., 2002).

This research focuses on commercial maize farmers in the summer rainfall region of South Africa. The maize-growing region is a polygon centred on the north-eastern Free State, extending into Gauteng, Mpumalanga, North-West, and Kwazulu-Natal provinces (see Figure 1.1). Commercial farms in this region experience a highly variable climate especially in terms of average temperature and rainfall. Planting dates, the timing of the rainfall onset and mid-season-droughts vary across the region, generally occurring later in the west than the east.

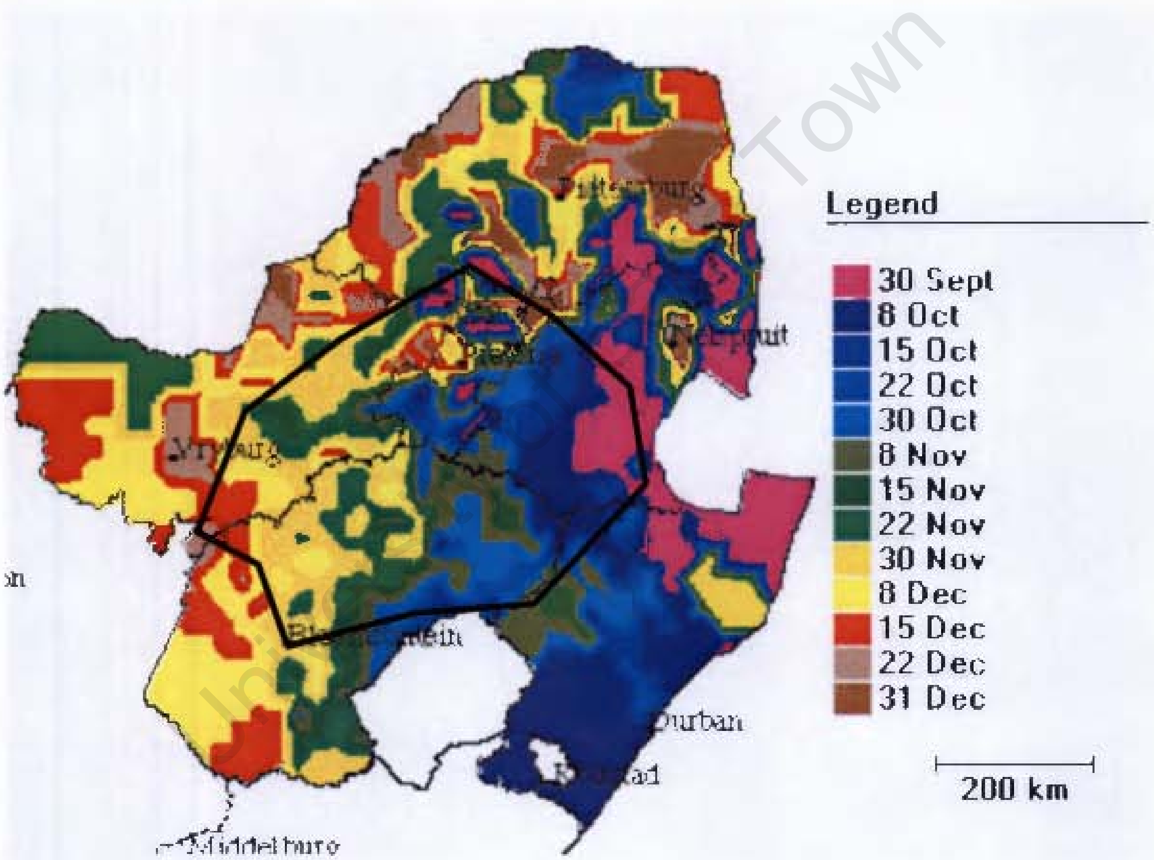


Figure 1.1. ***Optimal maize planting dates during a neutral SOI phase, with study area shown by the black polygon – courtesy of Maizevision (2002)***

At the University of Cape Town a seasonal forecast based on the HadAM3 GCM was developed, which is now being released operationally into the public domain. It seemed opportune and necessary to determine the uptake and utility of this and other forecasts to determine whether the forecast is optimally serving its purpose and further to determine how much of a role it plays in the decision making of agricultural sector users. The decisions in the agricultural sector would ostensibly include management and planning decisions, including response and adaptation strategies.

It is essential for the long-term application and utility of forecast products that users are engaged and involved in the evolution of the forecast product insofar as it can be tailored and moulded to their requirements and environments (Ziervogel, 2002). This will ensure that there is a greater likelihood that forecasts will be adopted and maximum benefits realised.

1.2 Assertions

When seasonal climate forecasts were first released it was envisaged that the information that was provided would make a significant impact on the planning and decision making of various sectors including agriculture. The efficacy and up-take of the forecasts amongst commercial farmers in South Africa was first investigated by Klopper and Bartman (2002) by using retro-active forecasts and canvassing farmers on the usefulness of the forecasts in their decision-making at the time. The conclusion reached was that users, specifically commercial farmers *should be* able to benefit from applying the forecast information, but due to various constraints the level of uptake was not established.

This research makes two initial assertions regarding the uptake and usefulness of seasonal forecast, which will be investigated and tested.

The first assertion of this work is that seasonal forecasts in South Africa are *not* generally used amongst maize farmers and that even if they receive them, it is unlikely that they will be beneficial. The status of the climate science producing these forecasts is not questioned, nor is the long term dynamism of the climate system ignored. The concept of a seasonal forecast produced from the latest available modelling techniques is regarded as a positive development. The assertion raises the query whether the end-users are gaining the benefits from the seasonal forecast product that were, and are, envisioned by the product developers.

The second assertion is that seasonal forecasts are only likely to be beneficial when they are more accurate, more focused, more specific and better disseminated than they are currently. This suggests that the forecasts do not currently fit into a cognitive model that enables them to be adopted by the users for which they were designed.

These assertions will form the basic thread of the research.

1.3 Aims and objectives

In order to test the above assertions, this thesis aims to determine and assess the uptake, use and application of seasonal forecasts amongst commercial maize farmers, and to determine the role that climate forecast information plays in their management decision-making processes. In doing so, the effectiveness and usefulness of forecast information will be critically analysed. It will also investigate the other factors that affect decision-making and assess the role forecasting can and does play in this regard. The outcomes would influence recommendations for actionable changes to forecast content, appearance, interpretation and dissemination.

The thesis focuses on 3 distinct aspects; the format, dissemination and uptake of forecasts; the validity or usefulness of the forecast; and the dynamics of the decision-making framework of the user vis-à-vis the forecast. The information gathered could allow appreciable insight into the usefulness of the forecast, allowing forecast providers, analysts and distributors the opportunity of continual improvement, adaptation and sector-specific tailoring, in order to better serve the needs of the agricultural community.

The targeting of commercial maize farmers was premised on the assumption that if seasonal forecasts could be utilised by this highly mechanised, specialised and productive sector, then the economic benefits would be maximised (Arndt et al., 2000; Mjelde et al., 2000). This assumption does not ignore that seasonal forecasts may make vital differences to small-scale farmer livelihoods.

The aim will be achieved through the following objectives and research activities.

- Analyse information about the dissemination and uptake of seasonal forecasts
- Build up value-added forecasts through user feedback
- Examine forecast validation and build a simple tool for users to use to gauge the skill of forecasts for their region

- Develop an application matrix to determine relative usefulness of forecast components
- Determine cognitive decision-making frameworks and the part played by seasonal forecasts
- Analyse the role that marketing and financial instruments play in the success of maize farming enterprises
- Provide practical and actionable steps towards a more efficient and beneficial uptake, understanding and use of seasonal forecast tools

1.4 Chapter outline

This chapter has outlined the background and aims of the research as well as the assertions and main objectives.

In Chapter 2 the current status of forecast production is presented in the form of an edited and revised extract from a paper published in 2004 (Johnston et al., 2004). Various southern Africa forecasts and their methodologies are discussed and an analysis of sectors that are using them and/or adapting them is included.

Chapter 3 provides a motivational rationale for the research with a description of the problem in respect of seasonal forecasts and users. A comprehensive survey of the recent literature is provided.

In Chapter 4 the research methods that seek to extend the state of knowledge (as described in Johnston et al., 2004) are presented along with the experimental design and selection of participants. The full time-line and progress of the research is documented.

An analysis of the survey results in terms of dissemination, skill and uptake of the forecasts is presented and discussed in Chapter 5. In this chapter the skill of the forecasts is critically examined and a verification technique is designed, computed and analysed for the HadAM3 model produced by the Climate Systems Analysis Group (CSAG) at the University of Cape Town. The technique is designed to provide a simple but effective tool for users to be able to assess the usefulness of a particular forecast for a specific temporal and spatial domain.

Chapter 6 addresses a basic assessment of the cognitive decision making processes involved in commercial maize agriculture with respect to the forecast and investigates whether seasonal forecast information is, in fact, cumulatively useful. The element of risk and its relationship with agricultural decision-making and the impact that seasonal forecasts have will also be addressed. Various coping strategies are introduced and analysed.

The conclusions and an assessment of the validity of the assertions are presented in Chapter 7 with specific reference to the maize sector as well as recommendations for further research and application in other sectors. The useful of the forecasts is discussed and the role that they do, and still could, perform is highlighted. The constraints on this research as well as further research needs are pointed out. Finally the contribution of this research to the improvement of forecast production and uptake is submitted.

Chapter 2: Seasonal Forecasting in SA[1]

2.1 Introduction

In South Africa, seasonal forecasts generally consist of an outlook of precipitation and temperature for the rainfall season of a region. Such forecasts are issued at least once a month, usually in advance of the next rainy season. In most cases the forecast is presented as a 3-month average, and can entail monthly updates for each subsequent 3-month period. Many such seasonal forecasts are produced for the Southern African region, by a range of scientific, academic and meteorological institutions (Basher et al., 2001; SADC-DMC, 2002; Harrison, 2005). In South Africa, some are produced as the output of research projects as an ongoing development, while others are produced as formal products being disseminated by the institution responsible.

In regions that lack sufficient water resources to irrigate and therefore depend on rainfall for farming, prior knowledge of the likely pattern of precipitation could lead to substantial improvements to food security as well as profits to larger-scale producers (Blench, 1999; Hammer et al., 2001). South Africa is a relatively dry country with variable rainfall regimes. Accurate climatic forecast information that could assist with the planning of planting, fertilisation and harvesting, could help increase crop productivity and profitability as well as reducing losses (Hammer et al., 1996; Jones et al., 2000; Hallstrom and Sumner, 2000; Patt et al., 2005). Most of the examples cited here are for crop production, but there are initiatives currently

[1] Edited and expanded excerpt of the author's contribution from Johnston et al. (2004) Seasonal forecasting in South Africa: an analysis. Climate Research 28(1)

underway to improve the utility of forecasts for livestock production (e.g. Hudson and Vogel, 2003;).

This chapter will serve to explore the improvement of the application of forecasts to the benefits of users, and also to guide forecast producers towards the production of more useful forecasts. The role of key institutions in the forecast system is assessed with a view to characterising the 'end-to-end' nature of the process. Such a characterisation will allow forecasters and application researchers to identify gaps in the process and suitable points for intervention to improve this process.

2.2 The process of seasonal forecast production

The process of developing a forecast varies according to the producing institution, but invariably involves a dynamical modelling approach or a statistical approach. Both approaches rely upon input data, which could be observed or modelled sea surface temperatures, historical climatic data, satellite information, or a combination of these (Goddard et al., 2001).

The predictability of seasonal rainfall results primarily from the influence of sea-surface temperatures (SST's), or so-called "boundary conditions", on the atmospheric circulation (Palmer and Anderson, 1994; Washington and Downing, 1999; Goddard et al., 2001). Throughout most of the tropical oceans, including the equatorial Pacific Ocean where ENSO events occur, sea-surface temperature anomalies may persist for up to six months or more (Goddard et al., 2001), making seasonal climate forecasting possible (Barnston, 2005).

The Southern Oscillation Index (SOI) drives the prediction of ENSO events, and the warming of the Pacific is the leading indicator. Most forecast models (dynamical and statistical) were able to predict the onset of the 1997/98 El Niño, albeit at lead times varying between 3 and 1 months, and were not inaccurate in the case of the United States (Barnston et al., 1999) or South America (Jones et al., 2000).

The relationship between Southern African rainfall and the El Niño phenomenon has been evident for some time. Ropelewski and Halpert (1987, 1989, 1996) showed a positive correlation between the Southern Oscillation Index (SOI) and Southern African rainfall. In Southern Africa, the wet summer season corresponds to the mature phase of the ENSO, when the range of anomalies in ocean surface temperatures and in atmospheric parameters is the largest.

El Niño impacts are at a maximum in the south-east of the continent, in January-February-March (Lindesay, 1988, Lindesay and Vogel, 1990). El Niño occurrences (warm anomalies in the Eastern Pacific) are usually, but not always associated with droughts in a large part of the Southern African region (Mason and Mimmack, 1992). In fact, the relationship between Southern African rainfall and El Niño/La Niña events seems to be temporally unstable. Seasonal climates may depend to a greater or lesser extent on SST variability in ocean basins other than the Pacific, suggesting that forecasts of SSTs in these other basins would be desirable (Mason et al., 1999). Indian Ocean SST anomalies, for example, correlate with eastern and southern African rainfall variations (Goddard and Graham, 1999, Reason and Mulenga, 1999), but forecasts of these SSTs are still in the developmental stages.

Rainfall records from previous years can, however, provide an indication of what can be expected during specific ENSO or (anti-ENSO) episodes. El Niño events differ in strength, and a range of rainfall outcomes can therefore be expected. This is where a specific SOI correlation has advantages. On the whole, for the period 1890 to 1989, El Niño events have led to mean negative rainfall anomalies (Figure 2.1). In contrast, La Niña conditions show positive anomalies.

Figure 2.2 shows enhanced probabilities of below-normal rainfall amounts over especially the north-eastern interior of South Africa during El Niño events. The likelihood of dry conditions is greatly increased in the JFM half of the season, especially since the 1970s (Richard et al., 2000).

The impact of ENSO events on South African rainfall patterns should not be over estimated but it is the magnitude of the impacts that are most important for the rainfall-dependent forecast user. In most cases its usefulness is proportional to the skill or accuracy of a forecast in determining both the event itself as well as the magnitude. In this regard it is important to recognise the relationship between forecast producers and forecast users. A forecast process that does not take into account the requirements of the end-user is not serving to advance its usefulness (Rosenzweig, 2001).

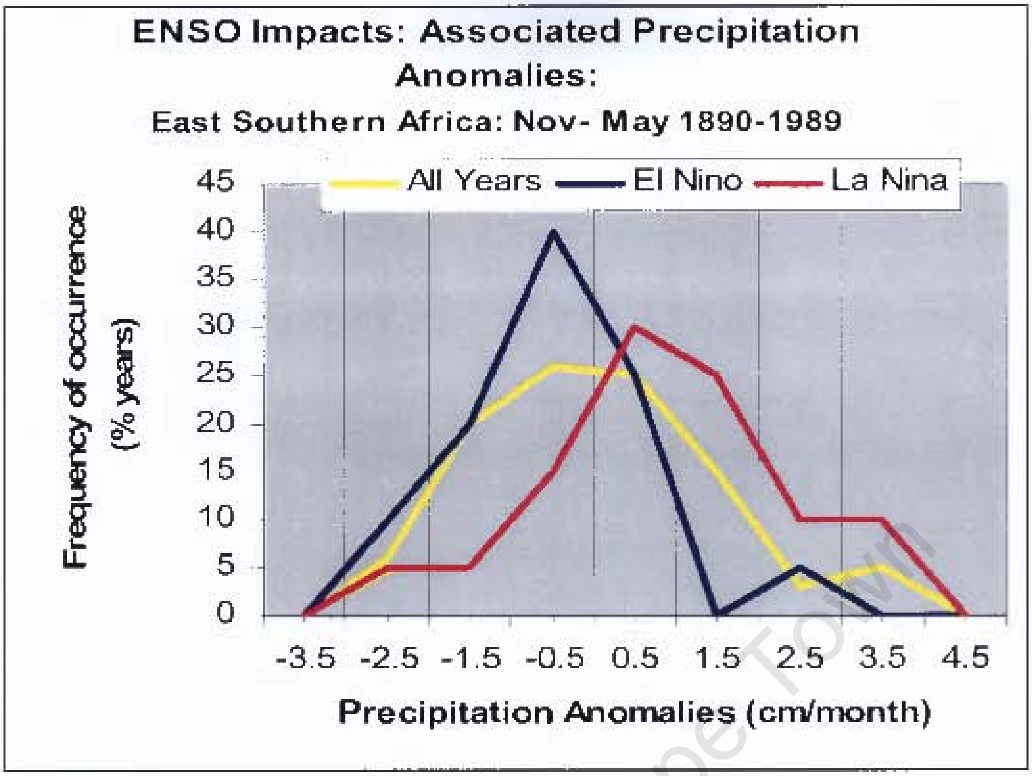
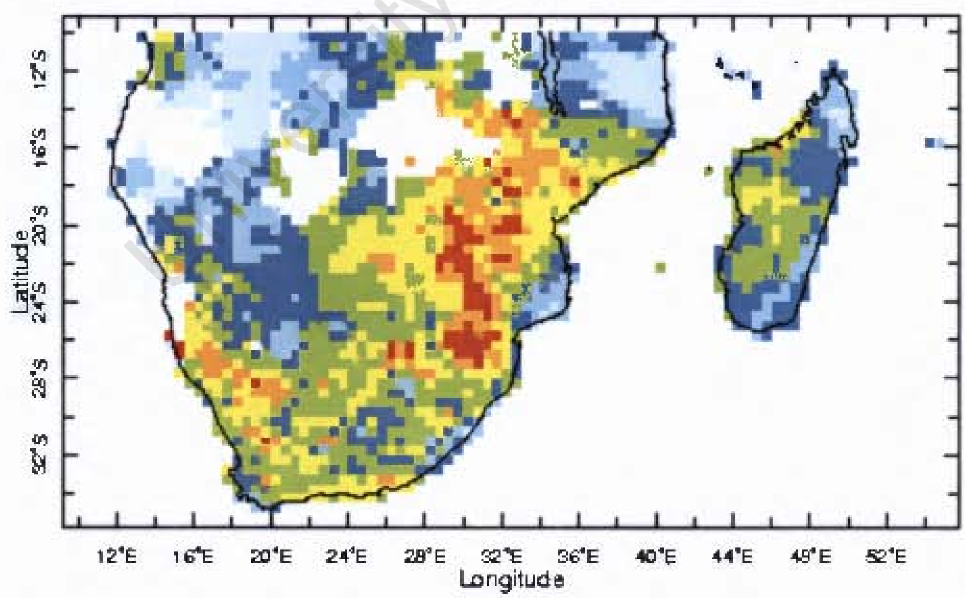
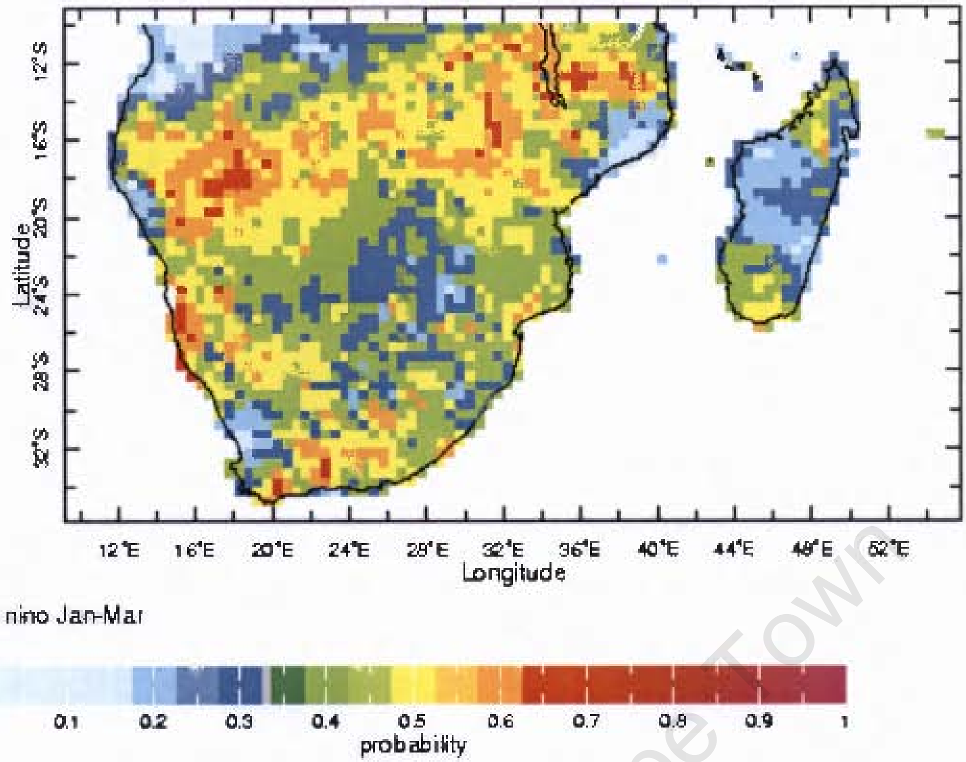


Figure 2.1. Precipitation anomalies of ENSO – East Southern Africa, Nov to May 1890-1989 (after IRI, New York, using data from NCEP, Climate Prediction Center USA)



dry nino Oct-Dec

i)



ii)

Figure 2.2. ***The probability of below-normal seasonal i) OND, and ii) JFM rainfall over southern Africa during the 10 strongest recorded El Niño events (NIÑO 3.4 SST anomalies OND 1950 – 1995)***

(After Mason and Goddard 2001, IRI website:http://iridl.ldeo.columbia.edu/ SOURCES/.IRI/.Analyses/.ENSO-RP/.0p 5deg)

El Niño events, although they are usually associated with below-normal rainfall over much of southern Africa, are **not** the only factor influencing southern Africa's seasonal rainfall. A warming of the Indian Ocean during El Niño events appears to be important in providing a linkage between southern Africa and the equatorial Pacific Ocean through the weakening of tropical convection over this region (Lindesay, 1988; Mason and Goddard, 2001).

The early successful identification of an approaching ENSO event is often regarded as more important than recognising the variation within a non-ENSO year (Stone and Meinke, 2005), but as Tapscott (1997) warns, will not necessarily lead to the reduction in the impacts if the social factors leading to vulnerability are not addressed.

As Blench states, there is also a problem with the indiscriminate use of forecasts.

> *The accuracy of forecasts depends on effective measurement of known predictors, model quality and local interpretation. In 1997-8, indicators showed that an El Niño was in progress, resulting in warm water off the coast of Chile, and drought in NE Brazil, southern Africa and Melanesia. Preparations were made throughout southern Africa, causing considerable scepticism when the expected drought failed to materialise. Similarly, predictions for January to March 1999, adjusted by the SARCOF meeting in December 1998, predicted above average rainfall in southern Africa, whereas observed rainfall was in fact lower than average. These technical failures have had the effect of enforcing more humility on climatologists and called into question the utility of widespread dissemination of forecast material.* (Blench, 1999)

2.3 Forecast producers in Southern Africa

A range of institutions in the Southern African region produce different types of seasonal forecasts, including meteorological services and university research groups. The Southern African Regional Climate Outlook Forum (SARCOF) process combines these forecasts, and produces a regional outlook every year. These provide a regional context within which local forecasts are configured, produced and used. SARCOF is the WMO-mandated regional seasonal weather outlook prediction and application process adopted by 14 member countries of the SADC.

2.3.1 Regional institutional processes

SARCOF facilitates information exchange as well as interaction among forecasters, decision-makers and climate information users in the region. Its main objective is to promote technical and scientific capacity building in producing, disseminating and applying climate forecast information in weather-sensitive sectors of the region's economies.

Seasonal outlooks generated by a range of methods at national, regional and international levels are presented to participants in order to formulate a consensus forecast for the region. The forecast generation applied by SARCOF (see Figure 2.3) entails the use of coupled ocean-atmosphere models, physically based statistical models and expert judgement. Probability distributions are established to indicate the likelihood of below-, near-, or above-normal rainfall for the region.

The mid-season correction is an important follow-on from the pre-season meeting. At this meeting, the season thus far is assessed and the latest model outputs consulted. The forecast produced can vary substantially from the pre-season issue and as many as 6 updates can be issued, as was the case in 2001/02. Fig. 2.4 shows the (i) pre-season and (ii) mid-season forecast for the same period (JFM) in 2002.

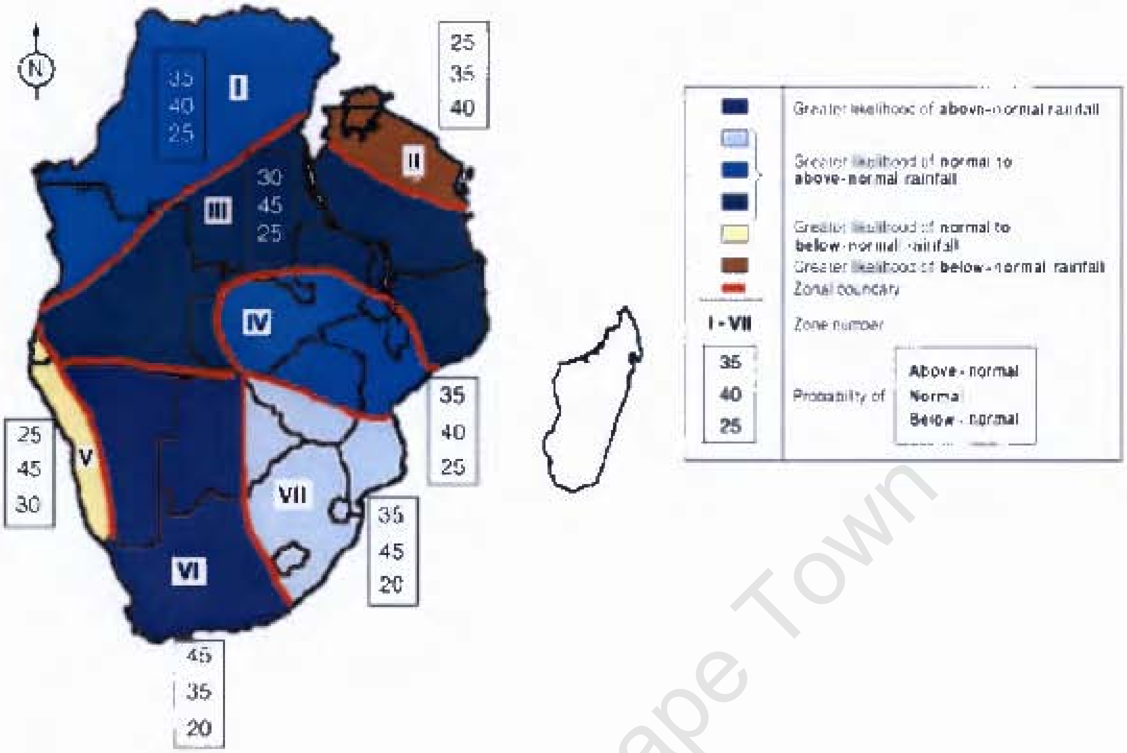


Figure 2.3. ***SARCOF consensus forecast September 2002. (source: DMC, Harare) Zone I: likelihood of normal to above-normal rainfall; Zone II: likelihood of normal to above-normal rainfall; Zone III: likelihood of normal to above-normal rainfall; Zone IV: likelihood of normal to above-normal rainfall; Zone V: normal to below-normal rainfall; Zone VI above normal rainfall; Zone VII: climatology***

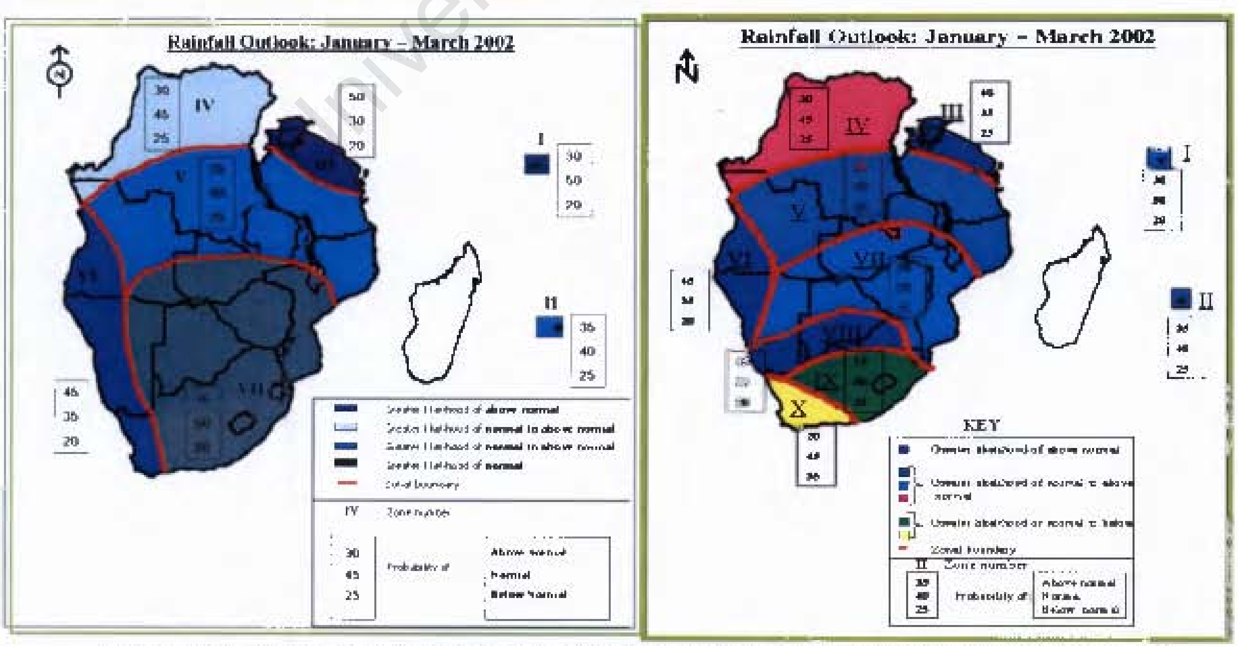


Figure 2.4. ***SARCOF forecast output for JFM 2002, produced in September 2001 (i, left), and December 2001 (ii, right) (source: DMC, Harare)***

The dissemination of the SARCOF forecast's information and products to the users is accorded high priority in the SARCOF process. In order for the outlook to reach all layers of the community, various media organs such as radio, television, newspapers, and press releases are used. The target groups are policy-makers, disaster management authorities, drought relief agencies, institutions responsible for food security, as well as other weather and climate sensitive sectors, including the general public. Some SADC member NMSs may choose to disseminate their own forecast, while providing access to the SARCOF seasonal outlook (and updates).

In South Africa, the SARCOF forecast dissemination appears to be limited to the SAWS website (www.weathersa.co.za/nwp/seasonal.html). It is generally reasoned that the SAWS resources and forecasts, having served as input for SARCOF, are adequately reflected in the SAWS long-term forecast. It can be seen from Figures 2.3 and 2.5 that the SARCOF consensus forecast differs slightly from the SAWS forecast for that particular forecast period. More recently the regularity of SARCOF meetings has declined and the lack of funding, information dissemination and high level input has reduced their potential efficacy.

2.3.2 South African Weather Service (SAWS)

The South African Weather Service is the country's national meteorological service, with a permanent representative at the World Meteorological Organisation (WMO). In terms of its WMO obligation, it is the primary weather and climate information service provider in South Africa. As one of the services it offers, the SAWS began the Long-term Operational Group Information Centre (LOGIC) in

1997. This centre was amalgamated with the SAWS Central Forecast Office in 2003 in an effort to produce a seamless forecast product range.

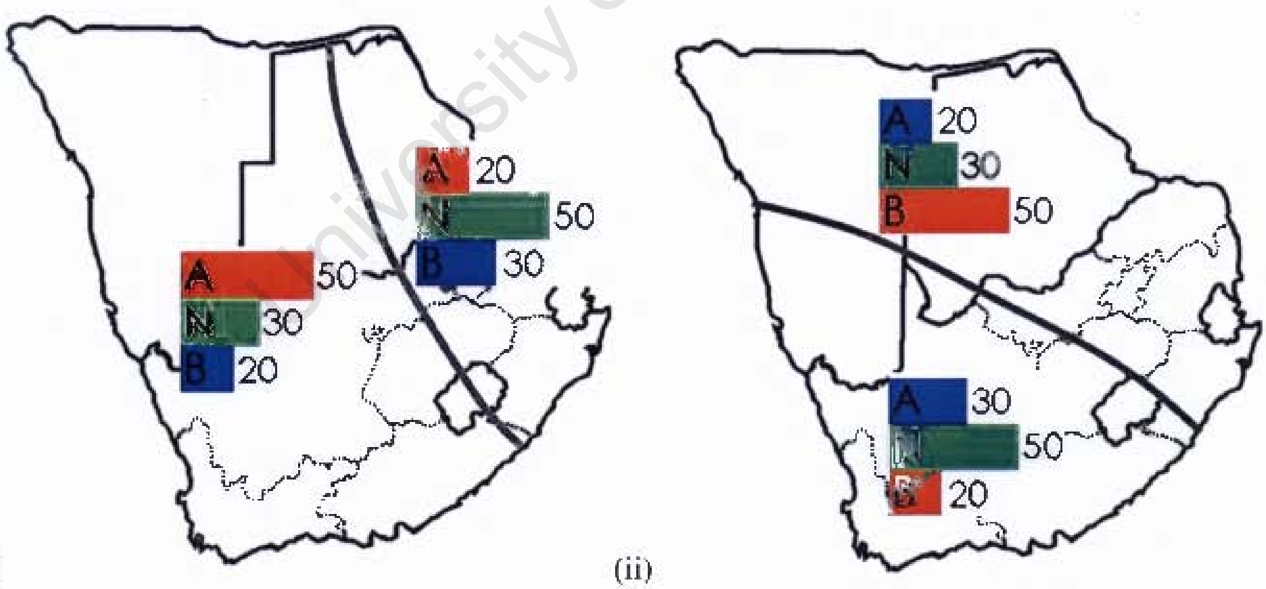
The scientists working on long-term forecasting projects produce and disseminate a monthly 3-month forecast through the Central Forecast Office. A multi-tiered forecast system consisting of a dynamic modelling process, combined with a statistical approach and consensus discussion is employed to produce the seasonal forecast (Landman et al., 2001).

A GCM that will forecast the atmosphere for periods longer than a month requires predicted sea-surface temperatures (SSTs) which are produced using a statistical method. Bias is determined from a series of retroactive forecasts (Tennant, 1999). The forecast produces continuous rainfall and temperature anomalies for the season and are issued as part of the forecast suite of the SAWS. These are updated weekly. In parallel, statistical forecasts of precipitation and temperature are made using canonical correlation analysis (CCA) (Landman and Mason, 1999). These are calculated through time-lag relationships between SA regional rainfall and global SSTs. These statistical models are trained and validated by historical data enabling forecast skill estimates to accompany the forecast.

Then statistical methods, where large-scale circulation fields generated by the GCM are downscaled (Von Storch and Navarra, 1995; Landman et al., 2001), are used to specific rainfall regions. The CCA regression equations are trained using observed circulation and regional rainfall to produce a regional rainfall prediction.

Finally a monthly discussion takes place among the long-term forecasters at the SAWS. Input from various local and international sources are analysed and a probability forecast is generated.

The dissemination of the SAWS seasonal forecast (Figure 2.5) is available via the SAWS website (www.weathersa.co.za/nwp/seasonal.html), selected email and fax recipients (including government departments, commercial agriculture and banks) and an automated cellphone number managed by the Central Forecast Office. Some interpretive guidelines are given with the forecast explaining, *inter alia*, the meaning of probability and the tercile system. These forecast maps are also presented every month on *AgriTV*, an agricultural television programme, and sent by request to journals such as *Landbouweekblad* for publication.



(i) (ii)

Figure 2.5. The SAWS long range seasonal forecast – Expected (i) mean temperature and (ii) rainfall, from August 2002. (source: SAWS)A: % above normal; N: % near normal; B: % below normal

Specific caveats are issued with the forecast:

- The potential of climate prediction arises NOT from timing and location of individual weather events, but for averages over months and seasons.
- Climate forecasts are distinctly different from weather forecasts, because they cover relatively large regions over a long period of time.
- The weather at particular locations and at specific times may sometimes appear to contradict the climate forecast, and
- Seasonal forecasts are NOT suitable for small, localised areas for specific days.

The latter is very apt for individual farmers where it infers that the scale of the forecast is unsuitable for specific small areas, but the reference to specific *days* is misleading, as it could be argued that even at a seasonal time-scale, the forecast is an average prediction for the entire indicated region.

During 2008 SAWS intends replacing consensus forecasts that with multi-model ensembles that are developed with higher resolution and consequently greater opportunity for tailored products. (Figure 2.6)

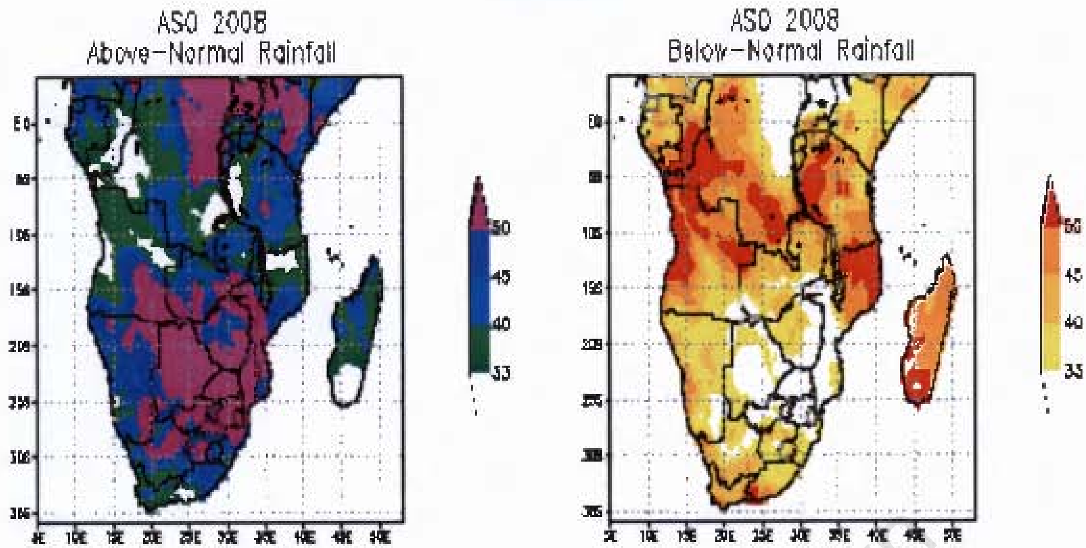


Figure 2.6. ***The SAWS long range seasonal forecast - Multi model ensemble forecast ASO 2008 (SAWS)***

2.3.3 University of Cape Town

At the University of Cape Town, seasonal and monthly forecasts are made using the United Kingdom Meteorological Office Atmospheric General Circulation Model (AGCM) HadAM3. The mixed phase precipitation scheme is included in the model integrations as this improves the model precipitation over Southern Africa. A 10-member ensemble of the HadAM3 AGCM has been integrated forward with observed (Reynolds) SSTs.

Forecasts are produced for 6 months into the future using forecast SSTs, which are constructed by adding the COCA (CSIRO Australia) model's SST forecast anomalies to the Reynolds SST climatology, except where persisted observed SST anomalies are used for the first month.

The 3-month average forecasts are expressed as anomalies of the ensemble mean minus the mean of a 15-year climatology produced using observed SSTs (1982–2000) (see Tennant, 2003, for a comparative verification of this climatology with that of the COLA GCM used at SAWS). For precipitation, the result is divided by the mean of the climatology ensemble and expressed as a percentage of normal (Figure 2.7). The contour lines indicate where the mean of the ensemble forecast was different to the mean of the model climatology at the 90% significance level according to a Student's *t*-test.

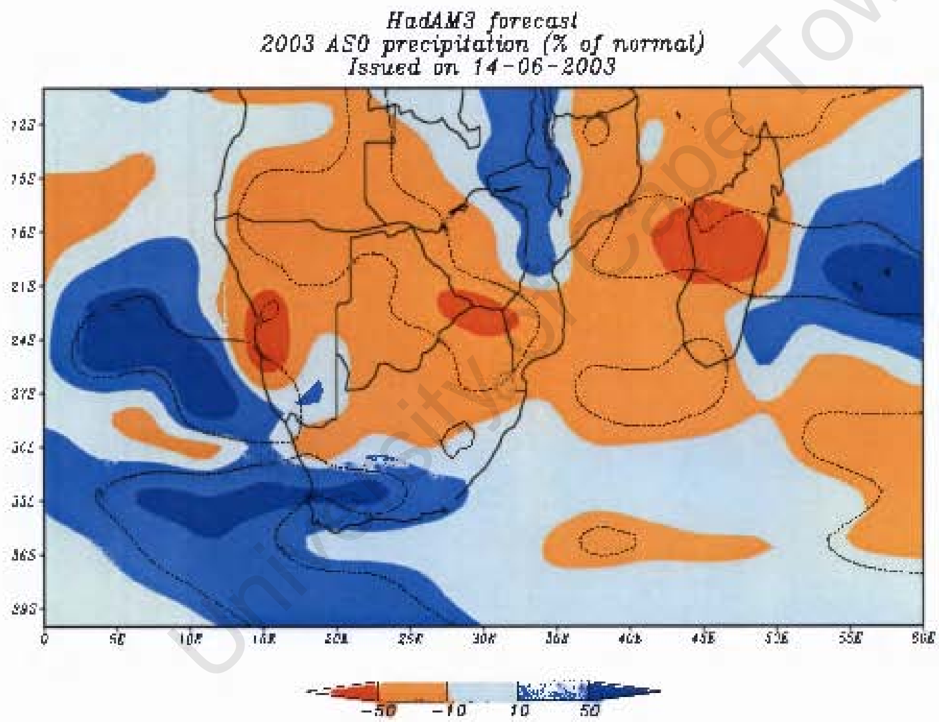


Figure 2.7. ***The CSAG 3-month seasonal forecast – expected % of normal rainfall for ASO 2003.***

The forecast is disseminated on www.gfcsa.net and www.myweather.co.za and directly as a resource for SAWS and other forecasting institutions. More recently individual months were added to the forecast, but are regarded as less skilful (Tadross, pers. comm.).

2.4 Intermediary institutions and agencies active in forecast application

Application of seasonal forecasts in South Africa is being undertaken by a number of institutions and potential end-users that rely upon the previous forecasts to produce specific applied forecasts for various sectors.

The Agricultural Research Council's Institute for Soil, Climate and Water (ARC–ISCW), for example, utilises the seasonal forecasts to develop and publish regular advisories for farmers (South African National Department of Agriculture 2003, Agricultural advisory; available at www.agis.agric.za). One of these is the Umlindi project, a remote sensing analysis to promote sustainable utilization of the region's climate, soil and water.

Additional resources such as Normalized Difference Vegetation Index (NDVI) images and feedback from users help to develop the agricultural advisory into a useful working document. For farmers, this could add significant value to the seasonal forecast. The advisories are distributed through the existing network of extension officers.

Maize Vision is an adhoc electronic product issued on a commercial basis by **Enviro Vision** in conjunction with the ARC-ISCW. The aim is to provide users (mostly commercial maize farmers) with a monthly (in-season) analysis of the received and anticipated monthly rainfall, as well as the significance for specific activities in the maize-growing region.

It is based on the latest observed SSTs from the Drought Research Unit (Queensland, Australia) and reported SOI (Australian Bureau of Meteorology), and uses a rainfall and crop model, respectively, to predict rainfall and crop yields for specific districts based on their rainfall records. Sea surface predictions are analysed and their correlation with the ENSO phases and the subsequent effect on rainfall and temperature are discussed. From time to time crop scenario estimates are published for each province and the possible influence on prices discussed. Maize Vision's aim is to give farmers (and other sectors) useful information from which pertinent decisions can be made. The decisions that could be influenced (as far as farmers are concerned) would include the selection of crop types, seed cultivars, fertiliser application, and even, as shown in the 2002/03 season, whether or not to invest in market futures, whereby a selling price is fixed ahead of time. Some limited advice is given to the recipients as far as climatic and crop conditions are concerned. The following excerpt and rainfall probability maps (Figure 2.8) are taken from Maize Vision No. 46, issued in June 2003:

> *The RSA maize crop for 2002/2003 is estimated at about 8.6 to 9 million tons but controversy over areas still continues. Dry conditions hamper the planting of winter wheat and it is possible that the unplanted areas will go to early sunflower plantings for 2003/2004. Farmers are in a dilemma with large grain stock levels and low prices for most grain commodities in the country. The problem can grow in magnitude when farmers must take final decisions for next summer season. What is the best commodity to utilise water, especially when water is a restriction? From a pure production perspective maize is still the best alternative with the*

highest yields possible with enough available water. Taking commodity prices into account, the best alternatives at relative low water levels (but above a critical level) are winter wheat and sorghum. Demand for sorghum is small, winter wheat need special soil water conditions and cultivation and both are therefore not real viable alternatives. Groundnuts are a good alternative crop if available water is more than 450mm during the season and sunflower when water is very restricted. It seems that the price of especially maize will stay under pressure due to high grain stock levels, favourable USA conditions, strong rand currency, marketing pressure when farmers are going to need money to finance input costs and expected more favourable rainfall conditions for next summer.

Some conclusions:

- *Where possible it is currently probably better to plant winter wheat than sunflower in early summer*
- *Groundnuts are a very attractive alternative if more than 400 mm water is available*
- *Sorghum is currently a very good alternative provided that a market is established before planting of the crop*
- *Sunflowers are a good alternative only at very low water levels (and poor soil)*

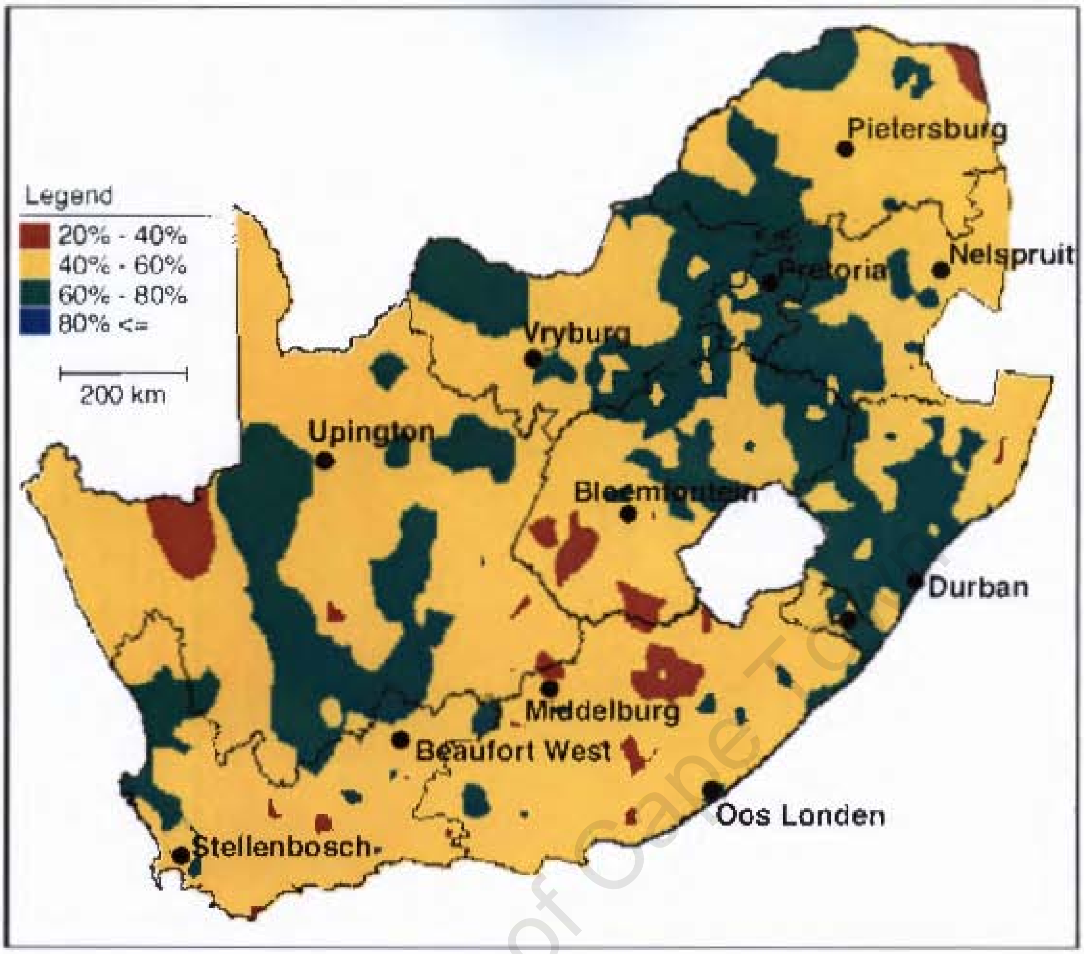


Figure 2.8. ***Probability (%) of exceeding median (normal) rainfall for October 2003 (Source: Maize Vision No. 46, June 2003)***

- *Groundnuts are not a viable alternative with available water levels lower than 350 mm*
- *Taking markets, labour and special production conditions for other crops into account, maize seems to be the only 'alternative' for mass production*

(Maize Vision No. 46, June 2003)

These recommendations are the closest to a *targeted* applied forecast available to the wider community of maize farmers.

Climate forecasts in the South African sugar industry are used by institutions such as **South African Sugar Association Experiment Station**, (SASEX) primarily with the emphasis on providing operational crop estimates (McGlinchey, 1999; Everingham et al., 2002). Singels and Bezuidenhout (1999) have demonstrated links between El Niño, rainfall and crop yields in the South African sugar belt. McGlinchey (1999) and Bezuidenhout and Singels (2001) based their crop estimates systems on the SAWS 3-month forecasts as well as the Climate Impacts Prediction Centre (CIP) based at the University of Zululand. Sugar cane production estimates for the South African sugar industry have been disseminated since 2000, normally starting in February prior to the opening of the milling season and updating estimates every second month thereafter. The information is valuable to a wide range of decision-makers functioning at different stakeholder levels within these industries.

At the farm level, growers could, for example, reduce their fertiliser applications and intensify some of their pest and disease controls if below average yields are expected (Sivakumar, 2006). At the mill level, decision-makers may use the information to estimate mill open and closure dates and allocate delivery slots to haulers and growers. Lumsden et al. (2000) observed large potential economic gains at the mill level associated with accurate and well adopted crop estimates. On a national level, stakeholders (such as the South African Sugar Association) may use the information to improve industry competitiveness through strategic financial and marketing planning (Everingham et al., 2002). There is still scope for future improvements to these systems. Bezuidenhout (2001) and Everingham et al. (2002) highlighted the incorporation of climate forecasts with longer lead times, web based information dissemination, more frequent updates and estimates starting in

September prior to the following year's milling season as areas of likely future research.

During this research it was investigated whether, and in which way(s), forecasts such as the above were used/not used by maize farmers in the study area.

2.5 Forecast accuracy and usefulness analysis

For forecasts to be useful a number of factors are required. These include an indication of their reliability, the skill-level of the forecast and the degree of uncertainty of the forecast. The accuracy of a forecast can be regarded as the level of agreement between the forecast and corresponding observations. The difference between these two is the *error* of the forecast. The verification of forecasts should reveal how likely there is to be error in the forecast and is, as such, part and parcel of their development. No single measure can reflect the 'accuracy' of a forecast and they are usually assessed according to a combination of the following:

1. Skill—the accuracy of a forecast relative to the accuracy of forecasts produced by some standard procedure. Climatology, persistence and chance (guessing) are considered to have zero skill

2. Reliability—is the average agreement or disagreement between the stated forecast value and the observed value

3. Resolution—the ability of the forecast to distinguish between predictions on a spatial and temporal scale. A high resolution forecast would be able to accurately distinguish between an area with a 50% chance of rainfall and an area with a 80% chance

4. Sharpness—this is the attribute of a forecast to tend towards a categorical prediction of 0 or 100%. It is important when predicting 'all or nothing' events like tornados, hurricanes and hailstorms. Neither the skill, nor the resolution of the forecast is reflected by its tendency towards sharpness

5. *Uncertainty*—this relates to the 'difficulty' of the forecast situation. Elements of uncertainty in a forecast make it very difficult to predict elements at all, let alone with a degree of skill or with high resolution

(after Stanski et al., 1989)

Thus, a forecast's skill would generally be measured by how many times in the past it has been correct, compared to some reference data, such as a climatology (Mason, 2000). This would relate to the methodology used to produce the forecast and would make the methodology suitable for specific areas and unsuitable for others.

Despite improvements in production technique, methodology and technology, some uncertainty will always remain in climate forecasting (Petersen and Fraser, 2001). The forecasts should thus be regarded as shifts in probability distributions within a locality's climate.

Probability is used in forecasts based on specific conditions for which a forecast may have skill, and expresses this in terms of *uncertainty* for specific areas for a specific time period. Such probability forecasts can never be completely wrong because they assume inherent uncertainty. Forecasts that turn out to be inaccurate are invariably misinterpreted to be *wrong*, when the observed outcome was simply *less likely*. It is however still valid to criticise a high probability forecast when it is inaccurate, as uncertainty that must have existed in the forecast, whether in the model or the forecaster's mind, should have been made explicit to users.

Forecasters may be expected to have a responsibility to reveal the anticipated skill level as well as the uncertainty that exists within a forecast so that users can be sufficiently aware of the risks associated with acting on the specific information.

El Niño forecasts are especially susceptible to a high degree of variation that leads to difficulty in predicting climate conditions for the same degree of index strength. For example, the 1982/83 and 1997/98 events were both very strong as measured by changes in the Pacific, yet their impacts in Australia were completely different. Eastern and Southern Australia experienced a severe drought in 1982/83, resulting in damages amounting to AU$8 billion (Cane 2000), but during 1997 average to above-average falls were common in May, and a dry spell over winter was broken by widespread and heavy rains in September with crop yields showing little if any negative effects (www.bom.gov. au/climate/enso/#impacts).

The best example of this variation in Southern Africa occurred during the same episode. In 1997/98, indicators showed that El Niño conditions that previously had led to drought would affect many areas including Southern Africa. The SOI value for September 1982, prior to the 1982/83 El Niño, was –2.0, while in September 1997 it was –1.6. The media issued widespread warnings and preparations were made, but the expected severe drought did not materialise. The rainfall was in fact above-normal for most of the country. The existence of the El Niño was an undeniable reality, but the impact on Southern African climate was not well anticipated (Dilley, 2000).

It is intuitively possible that forecasts, especially when trained by specific signals, are more likely to be able to predict conditions outside the 'normal' range. It would seem to be more difficult to predict the conditions when there is no specific evidence of a 'dry' or 'wet' season. The range of normal conditions is most often one tercile or 33⅓% about the climatological mean.

Whereas this gives hope that extreme seasonal conditions will be accurately predicted, the large variation during 'normal' years can be exacerbated by poor forecasts especially if a dry period persists for a number of years. This would be a very typical situation for parts of Southern Africa. An agricultural drought (insufficient soil moisture to sustain crop growth), may be in existence before a meteorological drought (implying a current lack of rainfall) is recognised. Thus the prospect of agricultural drought may be overlooked by a forecast that predicts normal rainfall for a season following a dry one. For this reason forecasts need to be interpreted in terms of local conditions.

2.6 Forecast applications

Part of the end-to-end chain of forecast production and use requires focusing attention not only on the 'science' of the forecast in its production phase but also on the dissemination and use of the product. How can we better understand the 'context' in which forecasts are framed, embedded and used? What cultural, socioeconomic and political processes currently possibly frustrate the use and uptake of forecasts? Do we *know* and *understand* the environment in which potential clients and users of forecasts operate?

Despite being able to intuitively forecast some changes in the climate, most societies have organised themselves to accept a range of climatic conditions that may occasionally produce surprises or extremes. Some groups and sectors have developed skills to predict the surprises, while others have developed a range of mechanisms which help to cope with the changes. Still others have learnt to accept the surprises as being part of life (Stern & Easterling, 1999). With the advent of scientific forecasting, the ability to be forewarned about 'surprise' climatic conditions and their impacts may lead to substantial benefits to certain users (Thornton 2006). On the other hand, forewarning without the capability of *forearming* could be regarded as counter-productive.

At present, in Southern Africa, and as shown above, only a fairly narrow group of potential users receive forecasts, and a smaller group actually makes use of them. Agriculture, being heavily dependent on rainfall, comprises the main group of users. Efforts have been made in recent years to strengthen forecast utility to agriculture by targeting provincial and local scales of activity through workshops as well as extension officer training in interpretation of seasonal climate forecasts. Users in commercial agriculture have traditionally had greater access to seasonal climate forecasts than users in developing agriculture, as they can potentially approach forecast producers directly (within South Africa, and internationally) through a variety of available channels, including television, the internet and private consultants (Walker et al., 2001). They also possess the greatest ability and resources to effect adaptation to climate stress. The above-mentioned outreach effort for extension officers is partly an attempt to correct this imbalance and bring the potential benefits of forecasts to developing agriculture (Kgakatsi, 2001).

It has been shown (Cane, 2000; Johnston, 2004) that when seasonal forecasts are interpreted as being deterministic for specific locations and used as a guide by sectors such as farmers, they seem to be inconsistent and, in many cases, misleading. This happens, firstly, because the forecasts are probabilistic in nature and, secondly, are often not intended for direct use at a local scale for specific applications (Plant, 2000), but are disseminated as seasonal guidelines only (Nicholls, 2000). An example of this arises when a high probability for above-normal rainfall for a 3-month period is predicted. If a drier first month follows such a prediction in a specific region, can a farmer, who to a large extent relies upon a total amount of rainfall, expect that the following month would be all the wetter in his region to counter the dry period?

Increased forecast accuracy and resolution would improve forecast utility for users. The constraints listed above suggest that this may not be the case in the near future, however. Temporal and spatial scales of current forecasts are such that high-resolution forecasts are not practically possible. By increasing the resolution it seems that quality must be sacrificed. The specific nature of a forecast may enable it to predict some aspects of the future precipitation or temperature with more accuracy and these would be most useful. With this in mind it is important to focus on the specific needs of the users and to focus research efforts towards increasing skill and utility in these areas.

Forecasts may be available with a range of accuracy and levels of reliability—but if they are of any use to a particular user, how can their value be estimated, and how can they best be used? Various tools are available to help address such issues in seasonal forecasting. Examining the Receiver Operating Characteristic (ROC) curve (Mason, 1982) can facilitate optimal use of forecasts, and economic value can be estimated with simple tools such as the Cost/Loss Model (Murphy, 1997). Although analyses such as these are a good starting point, in practice the detailed applications have to be defined interactively with individual users or user communities.

Not only does this lead to confusion among farmers, but also frustration among forecasters, who feel their predictions are being misinterpreted (Farago et al., 1997). This emphasises the need for tailored forecasts that will meet specific user requirements, in terms of actionable and mitigating responses. It also highlights the need for forecasters to be aware that their products may be presented as having more meaning (and thus influence) than was initially intended.

At the SA Weather Service some application-oriented research (Klopper, 1999; Klopper and Bartman, 2002; Klopper and Landman, 2003, Klopper et al., 2006) has investigated user interfaces and dissemination methods. Commercial farmers were polled and the effectiveness and improvement possibilities of forecasts were assessed. A number of other researchers have investigated the uptake of seasonal forecasts in the Southern African region (Vogel, 2000; Walker et al., 2001; Archer, 2003; Vogel and O'Brien, 2003; Ziervogel and Calder, 2003; Ziervogel, 2004), and similar work continues.

Such work needs to not only focus on the match between the 'science' of forecast production but also to examine the wider societal context in which forecasts are embedded (e.g. local knowledge systems, the role of traditional knowledge), what causes problems to uptake (e.g. access to information, access to credit) and how these constraints can be overcome.

In the context of this dissertation, it will be investigated how effective and successful the dissemination and communication of the forecasts is with respect to commercial maize farmers

Chapter 3: Forecast Challenges

A Forecast Is Just a Forecast: It's Not a Guarantee

Farago T, D.A. Wilhite and M.H. Glantz 1997

3.1 Introduction

The most obvious sectors that could benefit from seasonal forecasts are agriculture, water management, transport and energy. In each of these sectors advance knowledge of seasonal variation can initiate planning and operational decisions that can reduce risk, maximise earnings, heighten preparedness and facilitate mitigation responses especially in anticipation of extreme conditions such as drought or flooding. It is within agriculture that most seasonal forecast application research has found footing, as climate variation has historically threatened the food security of people reliant on subsistence or small scale agricultural activity (Martin et al., 2000; Meinke et al., 2001; Murphy et al., 2001; Ingram et al., 2002; Stone and Meinke, 2006). It has also been pointed out that the benefits to commercial agriculture are also substantial and that changes in production at this level could have serious economic and food security impacts (Mjelde et al., 1998; O'Brien et al., 2000; Johnston, 2004).

The production of forecasts *per se*, however, is not sufficient for the benefit to be realised by the users within each sector (Podesta et al., 2002). The forecasts are usually issued by the institutes where the scientists have produced them and, in many cases, present detailed and thorough information in terminology and presentation style not particularly familiar to the user. Without at least a passing knowledge of how forecasts are produced, what the information they obtain means, and an idea of the level of skill or accuracy that they purport to have, many potential users of such a forecast would not be able to understand, let alone interpret, the information in the way as the forecaster intended. The question of where the responsibility of bridging this divide lies, i.e. the issuing agency, government, agricultural agencies or scientists, has been shown to be superfluous as, without an integrated approach, involving producers, users and others, the benefits of the forecasts are reduced by distortion, misinterpretation, poor communication, inappropriate presentation and content, and insufficient forethought and consideration of the targeted users (Ingram et al., 2002; Hansen, 2002).

3.2 Skill, scale and uncertainty

The skill of forecasts has improved significantly since the contribution of the Pacific Ocean temperature variations has been better understood (Murphy et al., 2001). The contributions of the Southern Oscillation and subsequent ENSO episodes account for predictable seasonal variation in many parts of the world. Because the sea-surfaces temperatures are considered as the primary drivers for climate variation, the relative stability of these temperatures over days and even weeks makes it possible for longer term predictions to be made. It is not uncommon for seasonal forecasts to be made 6-12 months in advance, although it is generally recognised that 3 month leads times are by comparison significantly more skilful. It has been shown (Katz and Murphy, 1997; Livezey, 1990) that even small advances in skill lead to proportionally larger increases in economic benefit.

Despite the increase in skill, it is by no means a given that users will experience the same level of skill at a local or farm scale (Hansen, 2002). The spatial resolution of global models is in the order of 2 x 2 degrees (representing an area of approx. 100km x 100km, depending on latitude). This means that forecasts are indicative of expected conditions on a macro or country scale. Within-country variation (depending on the size of the country) is very difficult to analyse. Essentially a forecast will predict the variation from the normal at the macro-scale and local variations need to be inferred from the overall picture. Obviously, this has consequences for an individual farmer and other localised users. The anomalies in rainfall, an element that is highly variable and discrete, may not correspond at all to the overall forecast situation. This is usually accepted amongst farmers, as historically regional variation has been noticeably large (Tarhule and Lamb, 2003). Some communities have, by contrast, not realised that their sub-region's climate differed substantially from another nearby (Podesta et al., 2002).

Forecast models vary in skill depending on the methods used to produce them. Accurate assessments of initial conditions (such as ocean temperatures and sea-ice) as well as a perfect understanding of the dynamics within the atmosphere are the prerequisites for a perfect forecast (Sugi et al., 1997). Since neither is possible, there is a limit to the practical predictability within the atmosphere.

It remains to be assessed whether farmers can be relied upon to appreciate these limitations of a forecast, or whether indeed forecasts are ascribed more skill than they can ever inherently possess (Farago et al., 1997).

The use of probabilistic forecasts has been the forecasters' solution to the climatic uncertainty. The value of probabilistic forecasts generally has been shown to be equal to or greater than the value of deterministic forecasts for all users of such forecasts (Murphy, 1977; Krzysztofowicz, 1983). However, by given statistical probabilities of an event occurring or, in the case of rainfall falling within defined classes of variation, there will always be a possibility that under similar conditions, a contrary result may be observed (Lemos et al., 2002). This produces an interpretative conundrum for the users of the forecasts. Having been told that there is always uncertainty inherent in a forecast, the user must now decide how to interpret the probabilities. How closely does 60% chance of above–normal rainfall approach a 'likely' outcome of that nature (Manning, 2003; Gigerenzer et al., 2005)? When for example, probabilities of 50:30:20 (Above-Normal:Normal:Below-Normal) are issued, can it be said that there is a 80% (50+30) chance of normal to above-normal rainfall, or conversely a 50% (30+20) chance of normal to below-normal rainfall? As both possibilities are equally true (although inaccurately interpreted, as the sum of the two percentages is not 100%), the user is faced with the decision of how to interpret the true message as well as how much confidence to assign to the forecast.[2] Thus the concept of a skilful forecast may not sit as easily with a user faced with such a decision. Added to that is the infallibility of probabilistic forecasts. Any given observed outcome may be *improbable*, but *possible*, and the forecast would in reality never be "wrong". This, compared to the nature of categorical forecasts, with Meinke and Hammer (2000) inferring that any categorical forecasting system is either wrong or dishonest,

[2] One respondent commented that by halving the "NORMAL" probability (in this case 30/2 = 15) and then combining with ABOVE or BELOW two percentages could be obtained which *would* add up to 100%, namely 50+15 = 65% of normal to above-normal and 20 +15 = 35% of normal to below-normal.

reflects the catch-22 situation in which users find themselves – the forecast that is easier to understand may be misrepresenting the truth.

An analysis of a variety of current forecast verification methods and definitions is discussed in detail by Murphy (1997). Measures of accuracy, such as mean error and skill scores offer a means of assessing the *quality* of a forecast, while the *value* of a forecast depends on specific-user situations. The forecast value/quality relationships are complicated by the underlying variety and selection of verification techniques (Murphy, 1997).

> *Since forecast quality is an important determinant of forecast value, detailed assessments of the various aspects of quality are a desirable adjunct to studies of the absolute and/or relative value of weather and climate forecasts.*
>
> (Murphy, 1997)

At best, seasonal forecasts in Southern Africa have little more than 50% overall hit rate or accuracy, when compared to a 33⅓/33⅓/33⅓ climatological probability (Landman, pers. comm.). In a verification study, Klopper and Landman (2003) found useful rainfall forecast skill (ROC scores higher that 0.5) during spring and autumn over the summer rainfall region in South Africa, but not during the mid-summer seasonal forecasts.

Whether forecast accuracy, skill, quality and value are all qualities that are individually or collectively *understood*, let alone *required* by users remains to be seen.

3.3 Uptake and constraints

The opportunities for the dissemination of forecasts have never been so numerous with the advent of the internet, and e-mail and cellular phone communication. Information can be transferred with detail and contain explanations in a way that can be downloaded, printed, distributed and demonstrated with relative ease. This of course assumes that the user has the facilities, knowledge, exposure and awareness to access and use the information, and herein lies the rub. Many potential users do not have easy access to this information. Some live in remote regions, some have little education, others simply do not understand the concepts involved, while others find the information contrary to their personal beliefs, culture or understanding of the climate (Gettelman, 2003).

This does not mean that forecasts have not been used with significant benefit to subsistence farmers. Several studies have shown that focused, supported and intensive use of forecast information within subsistence communities has made a positive contribution (Patt and Gwata, 2002; Phillips et al., 2002; Hudson and Vogel, 2003; Orlove et al., 2004; Ziervogel, 2004; Patt et al., 2005).

In South Africa, as discussed in chapter 2, seasonal forecasts have been produced by SAWS for a number of years at significant cost using vast computational resources and many hours of scientific input. Although a few attempts have been made to assess the uptake and utility of these forecasts (Klopper, 1999; Klopper and Bartman, 2002), it is not clear whether they are found to be useful to the various sectors to which they are directed. According to Bohn (2003) the underlying assumption that forecasts *per se* are useful, needs to be challenged. In some cases (Hudson and Vogel, 2003; Phillips, 2003) forecast information that is disseminated is restricted to ENSO predictions and the possibility of impending drought, which in itself may be valuable in mitigating against drought, but does not necessarily promote the usefulness of a forecast in neutral ENSO periods.

Klopper (1999), Bohn (2003) and others showed that the uptake of seasonal forecasts was limited by a number of factors and constraints viz., availability, lack of confidence, ignorance and lack of understanding concerning the forecasts, spatial resolution, timing and lack of verification. Lemos and Dilling (2007) question the usefulness (or "usability") of seasonal forecasts as a decision-making tool for the poor, due to accessibility and communication issues. The receptiveness and acceptance of forecast value is often in indirect relation to the weather dependence of users. This relates to the exposure and vulnerability of sectors to climate related events. When a user can benefit from forecast information without suffering serious consequences if the information is subsequently inaccurate, there is a greater degree of receptiveness. In cases where economic factors, such as poverty and lack of resources, come into play, incorrect forecasts, if acted upon, have the potential for significant losses.

The dissemination of seasonal forecasts has been receiving some attention. Previously the SAWS forecast was available only on the SAWS website, but since the introduction of forecast users' fora in 2002, the information has been made available more generally to agriculture and the media, for example at NaCOF annual meetings.

Research has shown that when forecasts are distributed to users, considerable synergy is obtained by having on-the-spot interpretation, guidance and explanation (Everingham et al., 2002; Hansen, 2002; Ingram et al., 2002; Doblas-Reyes et al., 2006). This can be done with interpreters, facilitators, social scientists, institutional extension workers and members of the community. The forecast itself then becomes a less intimidating and, in most cases, a more accessible tool.

It still seems, however, that various factors can conspire to limit the use of forecasts even when such extension work is performed. It is apparent that some users, even after explanation and training in basic application, still do not gain any useful benefit from the forecasts (Mjelde et al., 1988; Lemos et al., 2002).

3.4 Communication and application of forecasts

The mere communication of forecasts, as with any new information, is not sufficient to ensure maximum benefit to the recipients. Cognisance must be taken of the various constraints limiting the usefulness of forecasts. It is within these constraints that a further part of this research is located. Patt and Gwata (2002) identified six constraints when examining forecast application in Zimbabwe, viz., credibility, legitimacy, scale, cognitive capacity, procedural and institutional barriers, and available choices. Lemos et al., (2002) concluded that, in Brazil, factors limiting the effectiveness of forecasts included inadequate skill, inaccurate application of the information and a disregard of the user's actual needs and decision-making behaviour. Nicholls (1999) showed how the presentation of forecasts, especially in the case of probability, was often couched in ambiguity, personal biases (cognitive illusions) and jargon.

The difficulties inherent in forecast communication have not been ignored by scientists. Communication difficulties have been discussed and analysed at length, in conferences, meetings, reports and papers. The problem of communication is clearly not one that can be solved by addressing a single focus area. Communication consists of a chain of contributors and recipients each located in a reality and set of circumstances that is unique to them. To ensure effective and accurate communication requires an understanding of each component of the chain as well as recognition of the constraints preventing the maximum usefulness of the message being transmitted (Everingham et al., 2002; Klopper et al., 2006).

It is necessary (Stern and Easterling, 1999; Greenfield and Fisher, 2003) that a fuller understanding of the linkages between forecast producer and forecast user is established through research and collaboration. It is the responsibility of scientists as well as users to work together with institutional intermediaries to ensure that reliable, effective and useful forecasts are produced (Hammer et al., 2001) and that they are well communicated (Henderson-Sellers, 1998; Hartmann et al., 2002; Stainforth et al., 2007).

In order to produce more oriented and effective forecasts it is necessary to gain a greater understanding of the processes and tools involved in the analysis and decision making that a forecast user requires to inform his subsequent actions (Nicholls, 1999; Hansen, 2002; Patt and Gwata, 2002). Research into decision-making and the rationality of choice form part of communication theory that has direct bearing on how a user or potential user may react to a seasonal forecast.

3.5 Making decisions

Several options arise when a user is presented with a forecast. It can reinforce his/her own beliefs and attitude toward the impending conditions, usually leading to little or no new actions; it can be contrary to those beliefs and attitudes leading to a choice – either to alter the current view of things, and consequently his actions, or to ignore the forecast in preference to his own views, and essentially do nothing differently. Or, it can be completely ignored before even being reviewed by a potential user for reasons relating to legitimacy, language or method of presentation. Cash et al., (2002) refer to salience, credibility and legitimacy (see Box 3.1) as the three basic attributes of scientific information that are required to be able to serve policy decisions. They warn that efforts to connect knowledge to action may be undermined by focusing on one attribute at the expense of the other two. That is not to say that any one of the attributes may not be more important at a particular time nor situation, but that unless all three are addressed, the information may be disregarded (Meinke et al., 2006).

A term that participants coined at the 2003 National Academies' Roundtable on Science and Technology for Sustainability, to describe the production and utilisation of climate information, was *knowledge-action system* (Cash and Buizer, 2005). These systems were viewed as organised efforts to harness science and technology in support of social goals. In general, they encompass the set of relationships, actors, institutions, and organisations that set priorities, invest in and apply research, review publications/promotions, facilitate practical application and reinvention, and provide evaluative feedback on performance. It was suggested that these systems be used to improve producer-to-user relationships, information flow and interaction through co-operative strategies and dialogues. In all cases the basis for effective communication lay in salience, credibility and legitimacy. This approach is supported by Vogel and O'Brien (2006) who ask "who can eat information?" They encourage the commitment of institutional efforts towards the better understanding of the needs and demands of society to better manage climate risks.

* *Salience* relates to relevancy of information. Does it provide information that is needed to help make a decision?

* *Credibility* addresses the technical adequacy of information. Is it scientifically or technically valid or accurate? Is the information based on my standards of scientific plausibility and technical adequacy?

* *Legitimacy* concerns the fairness of the information process. Does the system seem unbiased in addressing my values, concerns, and questions and those of others I believe should be included in the process?

Box 3.1. *Basic attributes of scientific information required to serve policy decisions, (After Cash et al., 2002)*

Stone and Meinke (2005) supported a commitment to an interdisciplinary approach when developing seasonal forecasts, where climate and agricultural scientists, modellers, economists and farm managers were all participants.

The psychology of decision-making in this context illustrates how important a prior understanding of the users' situation and needs becomes necessary for an effective forecast. The aims of the forecast producer can then be aligned with the requirements of a user to facilitate decision making to the latter's benefit (Roncoli, 2006). The problems of bias and ambiguity could then be addressed. One way is to address the ways that misunderstandings arise or non-rational decisions are made from seemingly 'accurate' forecasts (Fischhoff, 1994).

Farago et al., (1997) give three stages in the misunderstanding of forecasts. First, there are false expectations about various forecasting models and their outputs. Various expectations are placed on models not only by the "decision-makers" and the general public, but also by experts of the climate-related impact field.

Secondly, there is insufficient understanding about the interpretation and application of a forecast to a specific case. When forecasts are made, they suggest that they cannot be regarded as useful until suitable responses to the information are also provided. Because of the potential consequences of the forecast, it is asked whether forecasters should not be more accountable within the decision-making process.

> *"Should forecasters consult with the users or consumers of forecasts in advance to ensure that the final product will suit their needs? Should forecasters train users in the application of forecasts to "real world" problems? Should forecasters provide more insight into the conditions, assumptions, and uncertainties underpinning their analyses?"* (Farago et al., 1997)

The third stage in the misunderstanding would be misuse referring to an inappropriate application or response based on forecast information. For example a forecast predicting a greater probability of "below normal" rainfall may prompt a user to plant a crop later in the expectation of better rainfall later in the year, whereas a more suitable option may have been to switch to a more appropriate crop.

3.6 Rationality and satisficing

The target audience of a seasonal forecast is not a uniform, even, equal or equally receptive group (Agrawala and Broad, 2002; Archer, 2003). Within each continent, each country, each region, each community and even each household, there exist specific cultural, social and personal preferences, biases, beliefs, attitudes, needs, and abilities and willingness to change. There exists for each person a finite amount of information that can be and is used to make decisions. This can be increased through acceptance of new concepts and points of view, but at any given moment decisions will be made using this finite amount of information, influenced by the environment and milieu within which it is made. This is referred to as *bounded rationality* (Simon, 1956; March, 1988) and it is within this rational space that a decision is made based on the information available.

It is often found that a person will develop "sensible" decision making procedures, given the constraining information, and act upon these decisions despite the possible availability of alternative and extra information. This amounts to the first available solution to the problem, i.e. the situation requiring a decision, a practice referred to as *satisficing* (Simon, 1956, Patt and Gwata, 2002). Some forecast users, finding themselves overwhelmed by the array of choice and decision options, settle for the forecast easiest to access, rather than the most suitable (Pagano et al., 1999).

How people and organisations define, characterise, and analyse the phenomena may be the cause of confusion (Wilhite and Glantz, 1985). Within their own minds decisions are made using rational processes, but these may contain apparent anomalies in behaviour. March (1988) identifies a further seven types of rationality[3] that depend on the information sources that an individual is subjected to, respects, is compelled by or limits himself to. Each has a basis in behavioural science and can explain to some degree what influences a specific decision. Einhorn and Hogarth (1988) described decisions as a compromise between truth, which represents consistency, and accuracy, representing reality noting that the truth upon which a decision is made may be derived from a false premise as long as it is consistent with that premise. This would have specific implications for climate forecast-based decisions.

Suarez and Patt (2004) refer to two issues relating to the risks of applying climate forecasts, those of *cognition* and *caution*. They recognise that constraints of choice result in predictable anomalies of rational decision making. The response to losses, for example, is more extreme than is the response to gains, and this impacts on any change to the status quo where the negative outcomes are more heavily weighted than the positive. This leads to *inaction*. This would appear to have a significant implication for accountable decision-makers – they would understandably want to avoid any decision regarding a seasonal forecast that *may* lead to losses, irrespective of the possible gains.

[3] Limited rationality; contextual rationality; game rationality; process rationality; adaptive rationality; selected rationality; and posterior rationality.

Cautious forecasts from institutions stem from a desire to minimise the amount of information for simplicity, but also to reduce the liability of any inaccuracies. They suggest further that scientists, for example, need to find the optimal amount of information, determine the risk-aversion status of the users and convey it appropriately. They then suggest that the long term benefits of providing new, selected information for users, far outweigh the relative security of the status quo encouraged by the availability of less information.

3.7 Cognitive dissonance

The analysis of the application of seasonal forecasts lies in being able to identify and explore the processes involved in evaluating forecast information, characterising and analysing the risks involved, finding out how these correspond to the overall risks facing the user, and then observing how the climate risk is brought into the decision-making process. When forecast information is analysed by a user, a choice is made between two alternative options. Whether the choice involves a change in behaviour or not, it may subsequently prove to be the apparent wrong choice. This may be the result of an incorrect forecast, incorrect interpretation of the forecast, or a rejection of the forecast information.

In this instance it is common to experience *cognitive dissonance*, a theory of holding two contradictory cognitions or understandings of something *at the same time,* which creates an uncomfortable dissonance that is often reduced by modifying or rejecting a contradictory belief to create greater consonance. In other words, the dissonance between simultaneous beliefs is what creates an uncomfortable feeling, which is then addressed by trying to alter beliefs or interpretations about one of the cognitions.

This may imply dealing with a decision that, in retrospect, seems to have been at odds with the best available facts (Festinger, 1957). It is common to experience mental distress, which is dealt with by a process of dissonance *reduction*. This entails developing attitudes that reduce the dissonance by finding more information to support the selected option or by gaining reassurance from others who have chosen the same option. Alternatively the *consonant cognitions* (those factors which supported the decision) are increased by finding moral or physical benefits resulting from the alternative option (Harmon-Jones and Mills, 1999).

The question arises whether similar cognitive dissonance is experienced when users make a "wrong" decision based on forecast information - a *cognitive climate dissonance.* Together with the decision making processes mentioned above, the rationalities and dissonance experiences of individuals could give great insight into the decision-making frame of reference that exists (Schwarz, 2004).

A greater understanding of a user's frame of reference would be of great assistance to both the producer of the forecaster as well as any subsequent interpreter, facilitator or extension agent. Knowledge of the user's cognitive state leading to decisions concerning the willingness, and thereafter the capacity, to utilise a forecast would provide insight into the degree of importance attached to climate forecast information and the constraints and limitations facing the user in terms of making reactive decisions.

It would seem that while the production and communication of forecasts is important *per se*, understanding the nature of uptake options and decision making processes is equally, if not more, important so that the consequences of the forecast can be foreseen, optimised and, if necessary encouraged or discouraged.

3.8 Some research questions

The problems with forecasts and their uptake as described in this chapter led to the following questions that needed to be incorporated into the survey design and structure so that the answers would support the objectives of the study.

- What role are seasonal forecasts playing in agricultural decision making?
- In which ways can forecast uptake be improved?
- Which part(s) of the forecast is (are) regarded as less useful?
- Assuming each farmer has his own limits of bounded rationality, what pathways of useful information from a forecast are followed towards making a decision? Which are not?
- What part does climate risk play within the risk identification and management strategies of the farmers?
- Can these perceived risks be incorporated into forecasts to provide a better "fit" for the users.

The methodology and design of surveys is presented in Chapter four.

Chapter 4: The survey design and methodology

"If you can look into the seeds of time, and say which grain will grow and which will not, speak then unto me. "

William Shakespeare , Macbeth Act 1 Scene 3

As mentioned earlier, a seasonal climate forecast is produced by an institution, group or individual with the aim of communicating a long term prediction of climate variability to an end user. The nature and requirements of the end-user have seldom been uppermost in the modeller's mind and the method of application by the end-user even less so. Stern and Easterling (1999) laid down some guidelines for increasing the utility of forecasts by aligning the forecast output with the user's needs.

> *"A key to making climate prediction more socially useful is to develop links between those making the predictions and those who can benefit from them. The users need to know what kinds of predictions are made and what kinds may be possible in the future. The forecasters need to know which predictions are most useful and how they should be presented.*
> *Until now, there has been no process to try to identify such needs and consider whether they can be accommodated by scientific analysis. An important new direction might be in developing a process that tries more systematically than in the past to find matches between potential new scientific developments in climate prediction and the informational needs of users.*
> *One (strategy might be) to identify the climatic parameters to which particular sectors or groups are highly sensitive or vulnerable."*

(Stern and Easterling, 1999, p29,36)

Much progress has been made in this endeavour and it is safe to say that the discourse between user and modeller, or forecast producer, to be more accurate, has been greatly enhanced by fora such as SARCOF (Southern African Regional Climate Outlook Forum) and NaCOF (National Climate Outlook Forum). In each case, however, it still remains patently clear that the perceived needs and not the actual needs of the users are the main focus of discussion. In many cases, agricultural representation is limited to extension officers, researchers and scientists, when the farmer, as primary user, would be more useful.

4.1 Defining and selecting the maize-growing region

The guidelines for the growing of maize producing a commercial yield of at least 3 tons per hectare (in a year of average rainfall) are given as rainfall of between 350 and 450 mm per annum, and a temperature regime represented by an annual mean daily temperature equal to or higher than 19 degrees C, and a summer month minimum mean not lower than 13 degrees C (du Toit, 1999). Above 32 degrees yields are detrimentally affected, while a frost-free period of between 120 and 140 days is required depending on the nature of the selected cultivar. The nature of the maize plant as a C4 grass makes it a very efficient crop in terms of yield. 350-500 litres of water are required to produce 1 kg of maize. There are critical stages of growth that require sufficient water and the development and ultimate yield of the crop are dependent on rainfall during the flowering stage, specifically the two weeks before and after pollination (see Figure 4.1), and the drought sensitivity is highest between 20 and 80 days after planting (see Figure 4.2). It is during these periods that forecasts are most closely watched. The notorious mid-summer dry spell is a variable that has to be carefully estimated and its impact monitored in conjunction with these critical stages. Skilful forecasts are historically most appreciated if they can predict the dates of the dry spell (Klopper and Landman, 2003).

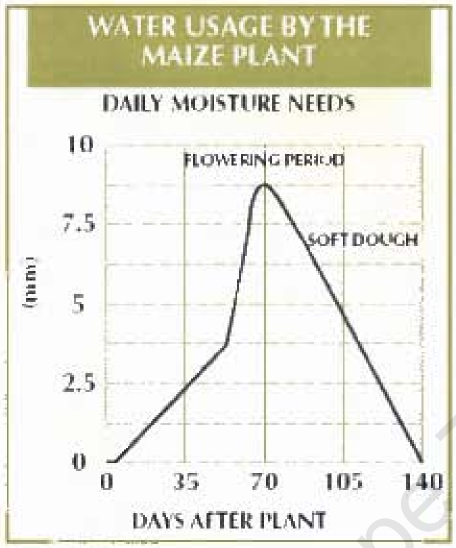


Figure 4.1. ***Water usage by the maize plant (courtesy Pannarseed)***

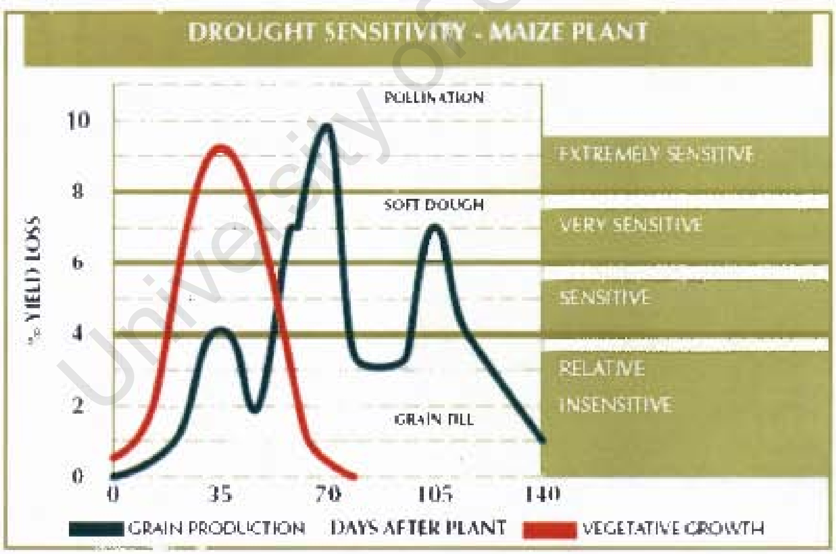


Figure 4.2. ***Drought sensitivity of the maize plant (courtesy Pannarseed)***

The area suitable for the growing of commercial maize has traditionally been described as the "maize triangle", later the "maize quadrangle" and more recently the "maize region" geographically delimited by the towns of Bloemfontein, Christiana, Zeerust, Warmbad, Machadadorp, Piet Retief and Ladysmith. The geographical area planted by commercial maize has been influenced by the development of different cultivars, increased irrigation opportunities and advancements in technology.

The current area includes parts of seven of the nine SA provinces and comprises 3.6 million hectares. The average annual commercial production of maize amounts to approximately 8 million tons (http://www.southafrica.co.za/agriculture_29.html). This excludes large areas given over to subsistence or small scale growing of maize, where yields are much lower and the opportunity for the sale of surplus stocks is much smaller. The role of maize as a staple food for both rural and urban inhabitants has been steadily decreasing (more rapidly in the case of the urban sector) due to the availability of alternatives such as flour and rice products.

As a grain, maize is very versatile and in addition to a basic foodstuff in the form of meal, it is used in a processed form as ethanol and starch in industry. The starch is converted into food additives and other household products including beer, ice cream, batteries, mustard and paint. In South Africa's economy it is the largest locally produced field crop and still the most important source of carbohydrates for human and animal consumption. Local consumption of maize is approximately 7 million tons (http://www.southafrica.co.za/agriculture_29.html).

The sharp increase in food prices during 2002, as a result of prolonged drought conditions, had a severe impact on the poor and on food security in the southern African region as a whole. The SA government's responses centred on relief measures to supplement the income of the poor, contain price pressures on basic foods, and strengthen the ability of the poor to grow their own food. More than 100,000 tons of South African maize was donated to SADC countries

The SA government is also examining the feasibility of a longer-term food security programme to provide households with seeds and tools for subsistence agriculture (http://www.southafrica.co.za/agriculture_29.html).

The decision to survey maize farmers was taken with the above in mind. In addition, it was felt that as commercial maize forms the backbone of the grain production in South Africa and is certainly the most widely used cereal, the success or failure of the crop does and would, have a large impact on a wide range of people. If commercial farmers were able to use and apply the benefits of seasonal climate forecasts, it was hoped and expected that the impact would filter through to emerging and small-scale sectors. Klopper (2002) found that amongst forecast users in South Africa, commercial farmers (including maize farmers) were the most prolific. This could lead one to believe that the forecast is well received, well understood and well used.

4.2 The scope of the surveys and the study group

The surveys of commercial maize farmers were intended to determine the answer to three distinct queries:

i. Are farmers aware of seasonal forecasts and do they receive/access them?
ii. Do farmers use the information supplied in the forecast?

iii. How is the information useful, and what improvements or modifications could increase the usefulness?

The surveys were *not* intended to determine the monetary or economic value of the forecast. Translated survey questions are found in the appendices 1-4.

The identification, preliminary and final selection of farmers began with a general survey of maize growers at the NAMPO maize harvest show from 9-11 May 2003. At this show a small stall was set up and farmers were randomly asked to submit themselves to a short interview regarding maize farming and seasonal forecasts. Posters with examples of recent forecasts were displayed to fulfil an educational and publicity role as well.

The questions at this point were designed to find out the exact nature of the maize farming, the land areas that were involved, the percentages of income derived from maize and to gauge the vulnerability of the crop to the variation in climate. It was important to determine whether farmers had been exposed to any type of seasonal climate forecast, and if so to determine the origin, the nature (in terms of temporal and spatial scale), the dissemination method and the perceived skill of the forecast. Over 50 questionnaires were completed, of which 35 were found to be suitably and sufficiently completed (some farmers had negligible maize plantings, others had none). These were taken to be representative of non-targeted farmers and assessed their knowledge and use of seasonal forecasting products (see 4.2.1).

The second survey sample was elicited, with permission, from the mailing list of *Maize Vision*, a product serving maize farmers, consisting of mainly Southern

Oscillation Index (SOI) based rainfall projections and market discussions. An electronic questionnaire was sent to over 300 farmers and 25 completed replies were received from farmers in and around the defined maize-growing region.

These questions replicated the earlier survey with the difference that there was an assumption that they at least *received* a type of seasonal forecast and the intention was therefore to determine whether the forecast had had any impact on their farm-based decision-making. Each decision-making process was analysed in terms of the contribution that forecasts do at present could make in the future. Questions needed to be designed to gauge users' trust and confidence in the forecast as well as their understanding of what the forecast communicated. Their desire to receive further forecasts was tested and the requirements of such forecasts were sought.

Of the 25 replies, 17 were found to be suitable in that they cultivated considerable amounts of maize in the defined "maize-growing region" (MGR). These respondents were adopted as the study group and were sent seasonal forecasts every month from September 2003 onwards. The intention was for them to receive the forecast and comment on the format, interpretation and usefulness. These respondents formed the main basis for the study (see 4.2.2).

4.2.1 The profile of the respondents (non-targeted survey)

The contribution of this survey would be to set a baseline of information which could then be compared to the other survey groups to determine to impact of seasonal forecasts. These particular respondents were randomly selected from visitors to the NAMPO (National Maize Producers Association) maize harvest festival in Bothaville. Only farmers who actively farmed maize were polled and few had had any previous exposure to seasonal forecasts. The average farm size of the group was 1228 ha, with approx one third devoted to maize, and one fifth to other crops. On average each farmer derived 69% of his income from rain fed crops on just over one half of his total land. All but two farmers kept livestock such as sheep, cattle, pigs or poultry.

Despite never having seen a seasonal forecast as issued by SAWS or CSAG, over 72% said that they had been exposed to another form of seasonal forecast through television or radio broadcasts. (It was not clear whether these were actual *seasonal* forecasts or merely perceived to be so.)

From the results of this survey it was expected to gauge an overall awareness of seasonal forecast availability, as well as the general receptiveness of the farmers.

4.2.2 The profile of the respondents (targeted survey)

Although each respondent was approved on the basis of maize farming, the location of the farm and the variety of crops grown was also important. The 17 respondents were located relatively evenly throughout the main MGR and each either had an alternative crop or raised livestock as well as maize. All were either part or full owners of their farms, and had previously received some of sort of seasonal climate information. Among these farmers the average farm size was 1772 ha with 40% devoted to maize and a further 16% to other crops. The percentage of total farm income from crops was almost in line with the previous group at 75% off 56% of the land.

The survey to this group focused on their reaction to the seasonal climate information that they had received. It had been exclusively provided by Maize Vision and none had received any other forecast information from either SAWS or CSAG, but had been exposed to short term forecasts in the media (the inference from this is that the non-targeted survey group were possibly referring to these). 100% of the group expressed the desire to receive further seasonal forecasts (of which 89.5% preferred the format of the CSAG forecast to that of SAWS). This facilitated the decision to go ahead with the targeted interaction using the CSAG forecast as well as the SAWS forecast formats.

A personal follow up visit to each respondent was made in August 2004, after a year's worth of monthly forecasts had been sent out, when a second questionnaire tested their response to the forecast and comments on it including suggested changes and improvements.

The forecast format was adapted and more targeted information included as information was received from the study group until it evolved into the final format around August 2006.

4.3 The compilation of the forecast

The forecast forms a very important part of the research. It must be compiled form freely available information and be communicated as straightforwardly as possible. In this way its current efficacy and usefulness can be assessed.

The forecast that was initially sent to the list of respondents selected from the targeted group was based partly on the selection criteria they submitted and partly by the information available at the time. Although many of the questions in the initial survey were related to that specific forecast, others were designed to elicit users' attitude towards forecasts in general and thus influence the nature of subsequent forecasts. Over the 3 years that the forecast was compiled and submitted, the format, nature and content was to change numerous times. This iteration process was intended to produce the most useful product possible for these users. Amongst the initial survey responses was an indication of the usefulness criteria of qualities of the forecast. These are summarised in Table 4.1.

Forecast Quality	**Responses**	
	Found it useful	**Found it not useful**
Temporal resolution	73%	21%
Spatial resolution	63%	32%
Lead time	1,2,3 months	Longer than 3 months
Forecast Months	S, O, N, D, J, F, M, A	M, J, J, A
Skill (correct at least 2/5 times)	72.7%	27.3%

***Table 4.1.** Usefulness criteria expressed by respondents*

36.8% and 31.6% of the respondents respectively felt that the seasonal forecast example shown to them had *fairly relevant* and *very relevant* information for their purposes and all but 2 respondents had e-mail as their first choice method for receiving forecasts. 79% of the farmers correctly interpreted the probability question as posed in the questionnaire and the same number felt *fairly confident* that they had interpreted it correctly.

72 % of the respondents from the first survey indicated that even if the forecast was correct on average only 2 out of 5 times, they would want to receive it.

The format of the UCT-CSAG forecast has been discussed in Chapter 3; it was designed to offer a 3-month forecast with 250km resolution over southern Africa. The precipitation forecasts are given for up to six months lead time with seasonal averages given as three month rolling means. The responses from farmers indicated that 1-3 month lead times were most appropriate, coinciding with other studies (Easterling and Mjelde, 1987) The scale on each figure is the percentage of normal precipitation for the period, with shades of blue indicating above normal and orange to red below normal.

The SAWS forecast was included with corresponding dates for precipitation as well as temperature. The forecast bulletin was prefaced by a short synopsis of the conditions and an interpretative note to the maps. The first forecast is given in Figure 4.3 below. Initially any differences between the forecasts were not interpreted. It was left for the users to see if they found difficulties in this respect – this would form part of the follow up analysis.

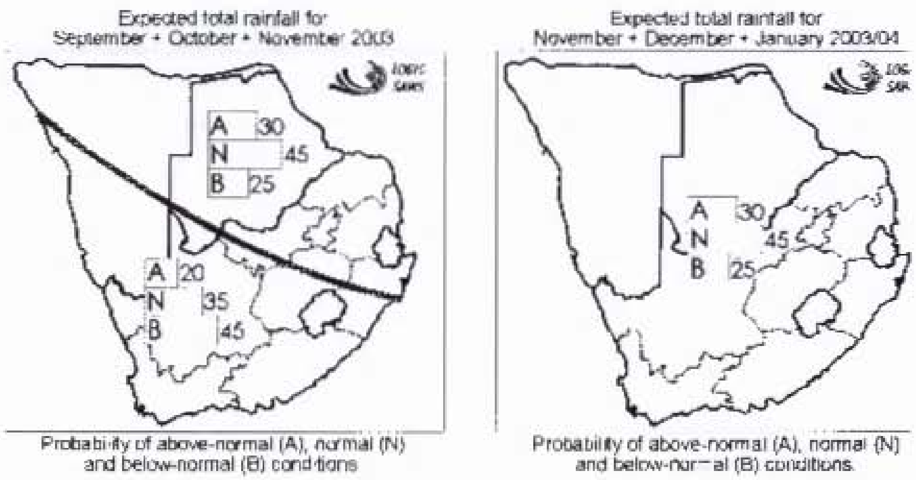
The overall intention was to issue as detailed information as was possible without creating unnecessary confusion. Follow-up interviews and feedback from farmers would guide the development of the forecast into a more useful tool

Date	**Action**
September 2003	NAMPO random questionnaires
September 2003	Targeted questionnaire to Maize Vision subscribers
September 2003-August 2004	Monthly forecasts disseminated
August 2004	Personal interviews and follow-up questionnaire
September 2004 – October 2006	Revision of forecasts and dissemination
May 2005	Follow-up questionnaire concerning yields in 04/05
August 2005	Follow-up questionnaire concerning hedging for 05/06 season after call for reduced plantings

Table 4.2. *Timetable of interviews and surveys*

SEP/OCT/NOV 2003 and NOV/DEC/FEB 2004

Seasonal PPT Outlook for Southern Africa- - Issued by the LOGIC, SA Weather Service, 24-8-2003

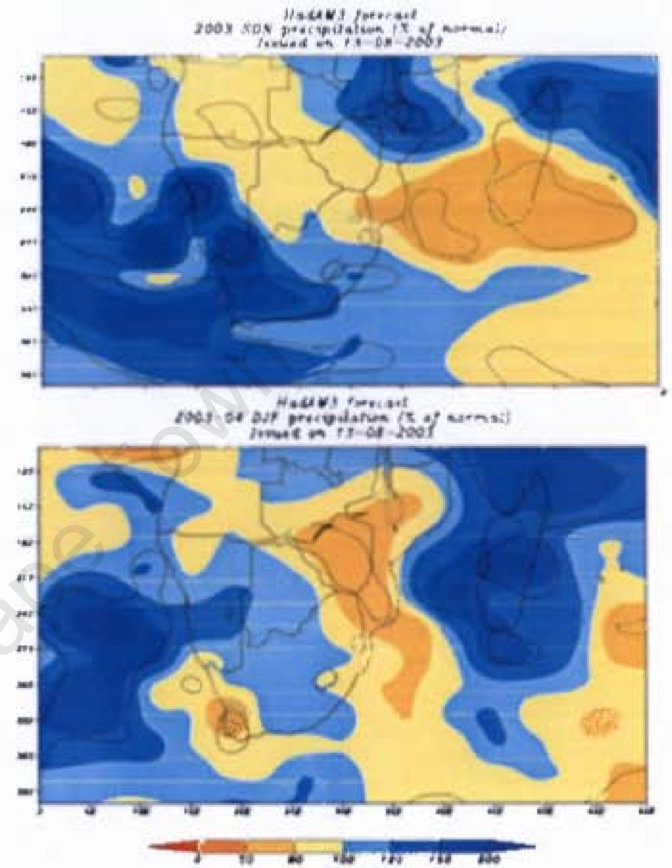


September + October + November 2003
Normal rainfall conditions (45% probability) are expected in the northern half of the forecast region, with a 45% probability of below normal rainfall conditions over the remainder.

November + December + January 2003/04
Normal rainfall conditions (45% probability) are expected over the entire forecast region.

SYNOPSIS: Current Sea-surface temperature conditions in the tropical Pacific are near average and neutral conditions (neither La Niña nor El Niño) are expected to prevail throughout the summer rainfall season. The outlook is for neither a wet nor a dry summer rainfall season to occur.

Figure 4.3. ***The first forecast compilation sent to the respondents***



University of Cape Town Seasonal Precipitation Forecasts Sep/Oct/Nov 03 and Dec/Jan/Feb 04

Anomalies indicate the variation expected from normal rainfall for the period. It is important to know what the normal rainfall for a location is, so that the percentages become meaningful. The scale on each Figure is percentage of normal, blue indicating above normal and red below normal.

The precipitation forecasts are given for six months lead time. The seasonal averages are split into two three month averages which correspond to the dynamical anomalies given elsewhere. The dashed contours shown on each map indicate where the mean of the ensemble forecast was different to the mean of the model climatology at the 90% significance level according to a student's T-test.

It is also important to stress the scale over which these forecasts are applicable. The GCM making these forecasts has a grid box size of the order 200-300 km square (NOT square kilometres which would be a smaller area). Furthermore the precipitation field is 'noisy' which means that taking even a single grid point as a forecast is not realistic. Hence an appropriate way to use these forecasts is to only pay attention to large areas (at LEAST the size of Botswana) that are coherent in the sign of the anomaly (above/below normal) and whose deviations are ALSO statistically significant.

4.4 The timeline and nature of the follow up

The follow-up questionnaires and interviews were integral to the assessment of uptake and use of the forecasts. These were timed to occur at the conclusion of each subsequent growing season, at a time when farmers were more inclined to be able to reflect on the past year and the contribution of forecast information to their decision-making.

The follow-up interviews focused much more on the actual uptake of the forecasts – how they were received and whether they were used – and the application of the forecasts – in which respects were they useful and in which not.

This included investigation regarding the cognitive processes that were involved in deciding whether using the forecast was worth it, the confidence with which they may use it again, and the dissonance that may have been experienced if incorrect decisions had been made as a result of using (or *not* using) the forecast information.

Each of the targeted respondents was visited on their farm in August 2004 for an interview. The main reasons for the personal visit were to obtain their responses to the forecast information first hand, to develop a sense of the degree to which they took the forecast seriously and to gauge whether their previous e-mailed responses had been a true reflection of their integration of forecasts into their decision-making.

Two further questionnaires were sent in May 2005 and August 2005 respectively, to gather information concerning the yields obtained during the previous season, and the decisions made regarding futures contracts and hedging on the SA Futures exchange (SAFEX) after the Maize board implored farmers to cut back plantings by up to 50%.

The forecasts were, and continue to be, sent every month since September 2003; even though the winter forecasts were not deemed necessary, some farmers indicated that they would give an indication of the soil moisture expectations by the start of the new season. Each of the targeted respondents was visited on their farm in August 2004 for an interview. The main reasons for the personal visit were to obtain their responses to the forecast information first hand, to develop a sense of the degree to which they took the forecast seriously and to gauge whether their previous e-mailed responses had been a true reflection of their integration of forecasts into their decision-making.

Two further questionnaires were sent in May 2005 and August 2005 respectively, to gather information concerning the yields obtained during the previous season, and the decisions made regarding futures contracts and hedging on the SA Futures exchange (SAFEX) after the Maize board implored farmers to cut back plantings by up to 50%.

The analysis of the uptake, use and application of the forecasts provided some interesting insight into the initial assertions and is discussed in Chapter 5.

Chapter 5: Analysis and Interpretation of Data

Seasonal climate forecasting has progressed from an invoking of the gods for information, to a sophisticated scientific discipline; however, the application of this new knowledge may not be as universal as we may expect. Rather than trusting climate forecasts a farmer may be more prudent and have a moderate stocking rate, conservative cropping practices and a cash reserve. This strategy would have close to a 100% chance of tiding the farmer through variations in the climate. If a climate forecast has a 30% chance of being wrong it will not be hard for a farmer's own systems to have a better outcome. It is not the lack of rainfall that restricts production in most seasons. It is the lack of knowledge of the future.

Farmer in New South Wales, Australia

The analysis of the returned surveys took place as they were received and thus influenced the nature of questions in subsequent surveys. The data will be analysed according to the three queries described in 4.2, namely,

i. Are farmers aware of seasonal forecasts and do they receive/access them?

ii. Do farmers use the information supplied in the forecast?

iii. How is the information useful, and what improvements or modifications would increase the usefulness?

The analysis also follows the chronological sequence of the surveys and the responses.

5.1 Awareness of, and access to, forecasts

Seasonal climate forecasts are disseminated in three ways in South Africa: by direct e-mail, available on internet websites or by third party agents. Users would therefore not normally receive them unless they specifically requested them, searched on the web, or happened to receive them from a third party. This would appear to be a fairly random means of dissemination and this view was backed up by the vague answers given in the first questionnaire to non-targeted farmers.

From the random sample of 56 non-targeted farmers, 24 (43%) acknowledged having received some sort of seasonal forecast, of which 5% from Maize Vision, 15% from SA Weather Service and 64% another source (radio, television, newspaper, Prof Pienaar[4]), while 11% of the farmers received 2 different forecasts. The higher figure of "other source" indicates a general ignorance of seasonal forecasts as the most that these sources would be giving out would be brief "forecast climate descriptions", and not forecasts as issued by CSAG or SAWS. At the time, it was highly unlikely that any media agency was using the latter forecasts.

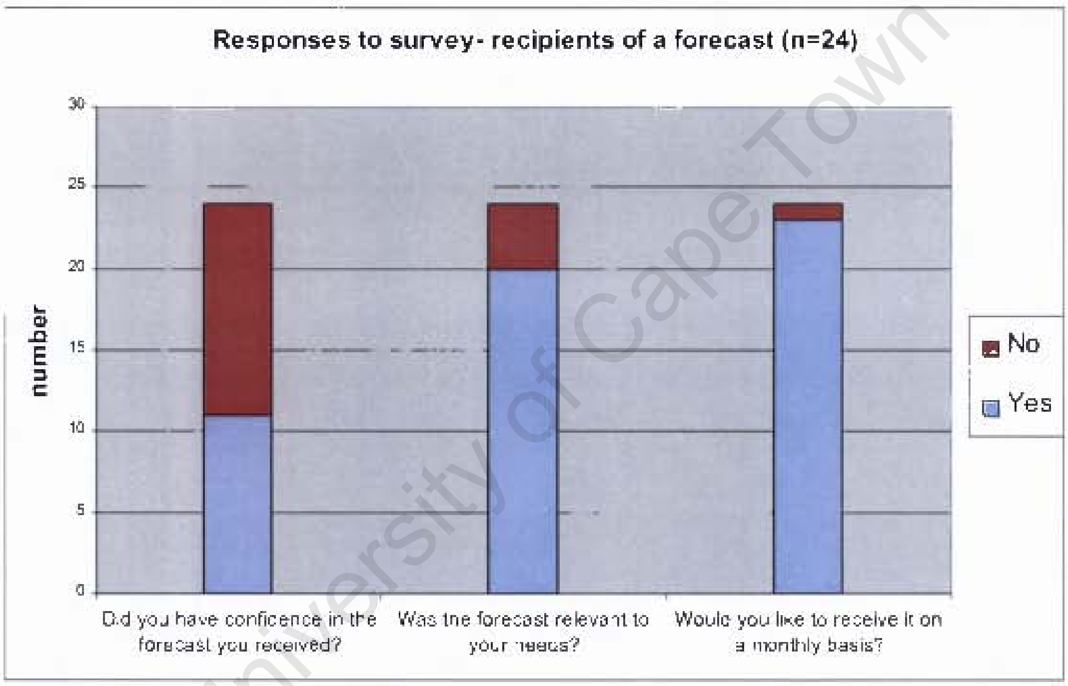


Figure 5.1. The responses of farmers who had received a forecast (raw values).

Only 33% said that they had confidence in any of the forecasts, but 55% indicated that forecast information was fairly, or very, relevant to their needs. Although mostly uncertain about what exact information was given in forecasts, all agreed that the expected rainfall compared to long term averages was of primary interest.

[4] Professor Peet Pienaar is a self proclaimed weather prophet who uses natural signs such as the phases of the moon as predictor. His forecasts contradicted the SAWS and CSAG seasonal outlooks in many instances. His forecasts are sporadic and seldom published. The temporal and spatial extent of his forecast is not comparable to the forecast used here, and no verification is available, but farmers were found to be receptive to, though doubtful of, his forecasts.

This group were met on a one-to-one basis at an agricultural show and were led through the questionnaire. When asked whether they would like to receive a forecast, 94% were in favour. Their preferred method of dissemination showed a wide spread (see Fig 5.2), indicating their possible lack of e-mail and internet access. Separate comments indicated that telephonic communication in rural areas at that time did not facilitate electronic access.

It was interesting that an equal percentage selected postage and Short Message Service (via cellphone) as preferred media. A posted forecast could contain far more information, diagrams and maps than SMS could, yet SMSs would undoubtedly be more convenient to send and more accessible, given the high proportion of cellphone owners among the general population.

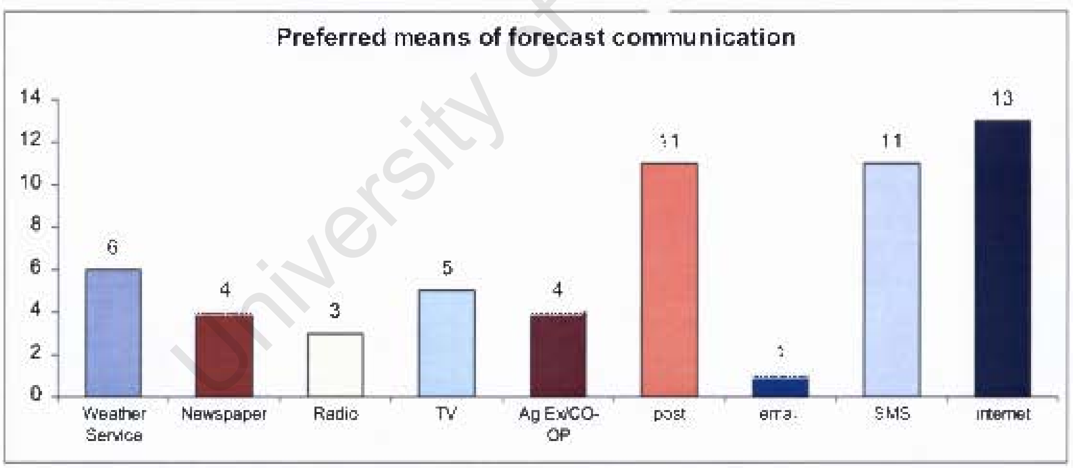


*Figure 5.2. **The preferred means of forecast dissemination amongst non-targeted farmers(raw values n= 56).***

Amongst the targeted farmers who had all received some sort of forecast (at the very least an SOI-based newsletter from Maize Vision), the responses were understandably different. Although none had received a seasonal forecast from anywhere else, 83% acknowledged using the information from Maize Vision. 37 %

found the information *fairly relevant* for their purposes and 32% *very relevant*.

All of the targeted farmers expressed the desire to receive SAWS and/or CSAG forecasts, with 90 % preferring e-mail as their medium of choice. 90% also stated that they preferred the format of the CSAG forecast to that of the SAWS forecast and, when pressed, most said that it looked like it was more detailed. 61% stated that they believed that the CSAG forecast would prove to be more accurate. It was pointed out to these respondents that greater detail did not infer any increase in accuracy, reliability or skill.

5.2 Usefulness of forecasts

The questionnaire that was sent prior to the study period commencing attempted to outline the requirements and expectations of forecast information. Although the respondents to the targeted survey had received some type of forecast before, and considering that at that time CSAG was in a position only to provide 3 monthly and monthly rainfall forecasts, the answers would help to guide future tailored forecasts. In the survey respondents were asked, based upon the forecast shown, whether they estimated that they would find the forecasts useful. 95% replied in the affirmative.

When asked to consider the usefulness of the limited spatial resolution of the forecasts, 63% stated *very useful* or *useful*, and 32% stated *not useful*. A number of farmers raised the proviso that the resolution was acceptable *if* the forecast was *accurate*. This was not to be the only time that this concern was raised and it became apparent that without any verification of the forecast available to farmers their confidence in the forecast was limited.

A question regarding the acceptable minimum accuracy for specific predictions of rainfall asked respondents to state the frequency with which a forecast would need to be right for each attribute of a forecast. The results, converted to average percentages are given in Table 5.1

Prediction attribute	**Minimum % correct predictions**
Total Rainfall: within Above-, Below- or Near-Normal categories	**78**
Prediction to within 20% of actual rainfall	**66**
Prediction to within 50% of actual rainfall	**70**
Prediction of Onset of rainfall to within 1-3 weeks of actual	**68**
Prediction of Onset of rainfall to within 3-6 weeks of actual	**82**

Table 5.1. *The minimum accuracy required by specific forecast attributes (expressed as average percentage correct)*

The results show that the farmers had very high demands from a forecast – effectively wanting a forecast to be, on average, correct 3 to 4 times out of 5. At first glance this seems to contrast with the earlier result of the non-targeted respondents showing that they would still want to receive forecasts if they were right only 2/5 times. However the difference between receiving a forecast and finding it useful, as well as the implications of the desired requirements, will be discussed further in chapter 6.

In order for a **seasonal climate forecast** to assist in making the management decisions below, respondents were asked to select a forecast characteristic or property that would be required or useful for specific activities, and to indicate their opinions by ranking each characteristic for that activity, using the following ranking.

1 – very useful	*2 – useful*	*3 – not useful*	*4 – don't know*

In the analysis, rank 4 was ignored and the sum of the rankings 1-3 was averaged for all the respondents giving a relative ranking to each attribute. These were also averaged for each forecast property. The cumulative averages were then categorised and colour-coded into ranges for *very useful*, *useful* and *not useful*. The result indicated the value of the forecast properties in terms of farm activities that would utilise that property, as well as the activity that stood to benefit most from forecasts and the forecast properties that were overall most beneficial to farm activities.

The forecast property deemed to be most useful was a prediction of the approximate timing and duration of dry spells. The activity that stood to benefit most from this was the decision regarding the planting date. Table 5.2 below shows the average scores for each cell of the matrix and categorises and highlights the scores according to their usefulness. Some salient points from the table include:

- The onset and duration of dry spells is more useful than the dates of onset or cessation of the seasonal rainfall
- The intra-seasonal temporal distribution of rainfall ranks higher than the specific monthly rainfall prediction
- Monthly rainfall predictions are more useful than 3-monthly ones
- Forecasts with more than 1 month lead time are relatively less useful than the other forecast properties.

Forecast property / Activity	Approx timing and duration of dry spells	Intra-seasonal distrib of rainfall	Prediction of monthly rainfall anomaly	Historical rainfall probability (based on ENSO)	Approx date of cessation of rainfall	Approx date of onset of rainfall	Forecast with more than 1 month lead time	3-monthly average rainfall anomaly only	Average temp anomalies	Average score
Crop Planting date	1.29	1.31	1.50	1.57	1.36	1.36	1.69	1.79	1.83	1.52
Amount of Land prepared	1.38	1.46	1.50	1.69	1.54	1.31	1.83	2.08	2.08	1.65
Type of crops planted	1.38	1.38	1.86	1.64	1.43	1.43	1.77	2.07	2.00	1.66
Irrigation planning	1.86	1.71	1.75	2.00	2.00	2.14	1.71	1.86	2.14	1.91
Stocking rates	1.90	2.10	2.00	1.73	2.10	2.09	2.00	2.00	2.25	2.02
Selection of crop cultivars	1.92	1.85	2.15	2.07	1.93	2.15	2.23	2.21	2.00	2.06
Borrowing money	2.20	2.30	2.14	2.22	2.40	2.60	2.11	2.22	2.56	2.31
Fertiliser purchase	2.42	2.45	2.00	2.23	2.36	2.33	2.36	2.00	2.64	2.31
Average score	1.79	1.82	1.86	1.89	1.89	1.93	1.96	2.03	2.19	

Key		
	Very useful	1.00-1.66
	Useful	1.66-2.33
	Not useful	2.33-3.00

Table 5.2. The scoring of forecast properties vs activities for which the forecasts are perceived to be useful. Each respondent rated the cells in the matrix according to the key (1, 2, or 3) and each cell was then averaged. Each row and column was also averaged and ranked to indicate the relative importance.

It was significant that none of the forecast properties, on average, fell within the *not useful* category, and this suggests that further information is welcomed by the farmers.

Research into dry spell duration and onset continues at CSAG but no predictive tools have yet been designed. The preference of disaggregated monthly forecasts is also receiving attention. Currently, forecaster modellers at CSAG have not assessed the skill of monthly forecast and it is felt that the rigid 30/31 day 'month' cannot be confidently predicted by the model.

These results were also presented to the SA Weather service at NARCOF 2004 and it was stressed that future forecast efforts should be focused on monthly predictions as much as seasonal. In September 2006, SAWS introduced their probabilistic monthly forecasts, and these were included in the subsequent forecast bulletins sent to the farmers.

One question that arose from discussion of 3-monthly versus monthly forecasts was the interpretation of the 3-month period forecast in terms of months. For example, if the 3-month forecast predicted below normal rainfall and the first month produced *above* normal, then were the subsequent months likely to be even drier to "make up" for the wetter month? This highlighted not so much a forecast modelling challenge, but a communication challenge.

Users need to have the answer to this query available to them. (In terms of modelling validity the wetter month does not infer that the 3-month forecast will be incorrect overall unless it differs significantly from the individual month's forecast. In this case, the forecast for those 3 months should be ignored and the forecast for the following 3-month period should be consulted.)

When asked how they would have reacted in three important decision-making areas if they had had prior knowledge (in hindsight) of the previous season's overall weather, most indicated that they would have done things differently in terms of crop selection and planning of plantings, but less than half would have selected a different cultivar. See Table 5.3 below.

Different Decision	N=19
Crop selection	**13**
Cultivar selection	**9**
Planning of planting	**12**

Table 5.3. *Number of farmers who would have made different decisions regarding some major on-farm activity with prior knowledge of the season's climate*

5.3 Uptake of forecasts

The uptake of a seasonal forecast would assume that not only is a forecast received and found to be useful, but that the information is actually included in decision-making processes that impact on their farming activities.

The information required to determine what the level of uptake was among the target group was obtained through personal face-to-face interviews a year after the initial forecast was sent. After having receiving 12 monthly forecast bulletins, it was expected that the respondents would be in a position to assess their reliance, trust and perhaps dependence on the forecast.

The questions differ from the first survey in the respect that they now assess the uptake and usefulness of 2 specific forecasts that were sent to them, firstly the official issued SAWS seasonal forecast and then a CSAG forecast with applicable comments orientated towards the specific user group.

5.3.1 Significance testing of the consecutive surveys

Those questions that were repeated in subsequent surveys were subjected to t-test significance testing, and the results are presented in Table 5.4 below.

Only 2 questions were found to show significantly different results after the personalised forecasts had been sent to the solicited group. It appears that the perceived *relevance* of the forecast increased after they were acquainted with it, but that the perceived overall *usefulness* declined. Among the non-significant results were decreases in usefulness in specific decision making aspects.

This in itself is significant in showing how the perception of a forecast's utility can change as a user realises the strengths, limitations and relevance of forecasts to their particular activity.

	Category		Time 1		Time 2		t statistic	significance	
	Min	Max	Mean	Std Dev	Value	Std Dev		%	
Did you believe the forecast?	0	1	0.73	0.4577	0.79	0.4258	0.2619	79.51	
Was the forecast relevant?	1	3	2.19	0.7500	2.57	0.6462	1.3226	19.57	*
Did the forecast assist your planning?	0	3	2.38	0.8851	2.14	0.9493	-0.7241	47.43	
Would the forecast have assisted with crop selection?	0	1	0.83	0.3835	0.71	0.4688	-0.5291	60.03	
Would the forecast have assisted with cultivar selection?	0	1	0.53	0.5130	0.43	0.5136	-0.4041	68.88	
Would the forecast have assisted with planting date?	0	1	0.68	0.4776	0.40	0.5071	-1.1533	25.71	
Did you find the forecast useful?	0	1	0.95	0.2294	0.67	0.4851	-1.3286	19.31	*
Average			1.18	0.53	1.10	0.57	-0.3229	74.89	
Number of questionnaires			**19**		**15**				

*** - statistically significant**

Table 5.4. *Statistical significance testing of selected variables concerning the use of and attitude towards the forecast, before and after receiving it.*

5.3.2 Survey Results

Some of the results are represented in Figure 5.3 below:

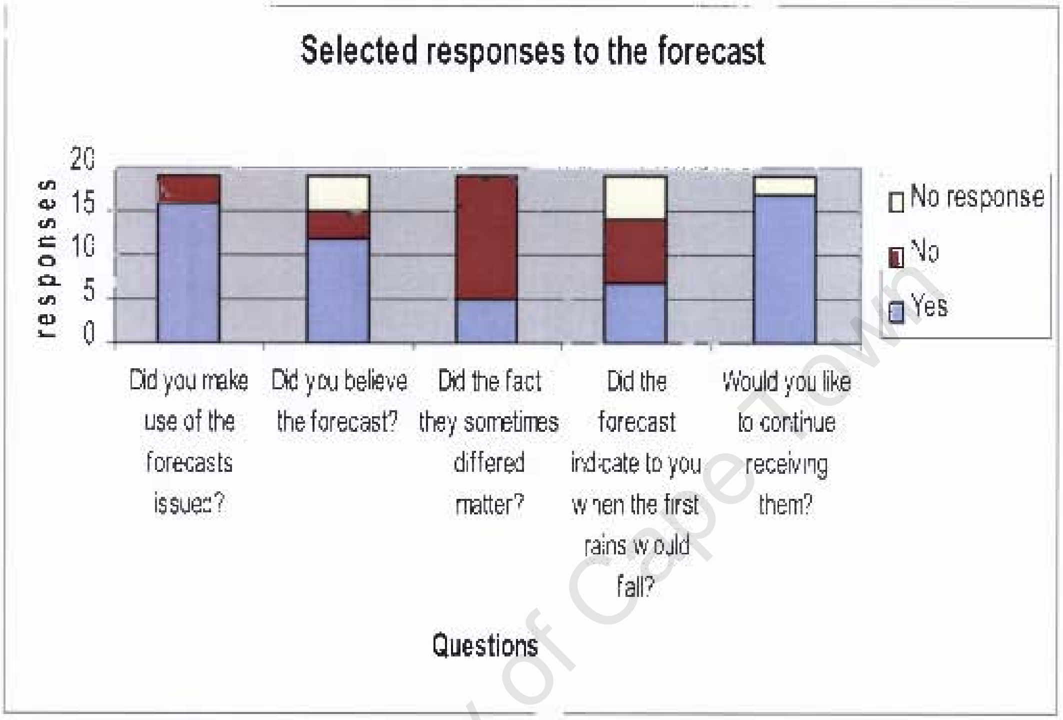


Figure 5.3. ***Selected responses to the post-forecast survey (n=19)***

From the questions above, some preliminary conclusions can be made:

- There is an overall positive response to forecasts
- Most found it useful, credible and would like to continue to receive them
- There is some misunderstanding about what the forecast stated; there is certainly no indication on the forecast when the first rains would fall, yet 38% indicated that there was

The questions of lead-time, scale and accuracy (or skill) were raised (see Figure 5.4). There was a unanimous desire (19 out of 19 responses) to see forecasts at a more detailed scale, but this is moot as physical modelling limitations exist which, until downscaled forecasts are an operational reality, prevent this. As far as lead-time is concerned, farmers did not really require long lead times, with well over 60% maintaining that 1-2 months was sufficient for their planning needs. This view is supported by the findings of Orlove et al. (2004) in Peru.

Figure 5.4. Lead time responses

Something that farmers did not comment on specifically, but in private conversation appeared to accept, was the difference in forecasts as the lead time was reduced. It was felt that the closer to real time the forecast appeared, the more chance it had of being skilful. In the example below, the forecast for November/December /January 2006/7 is shown as it was when forecast in August and then in September. The observed precipitation is also shown.

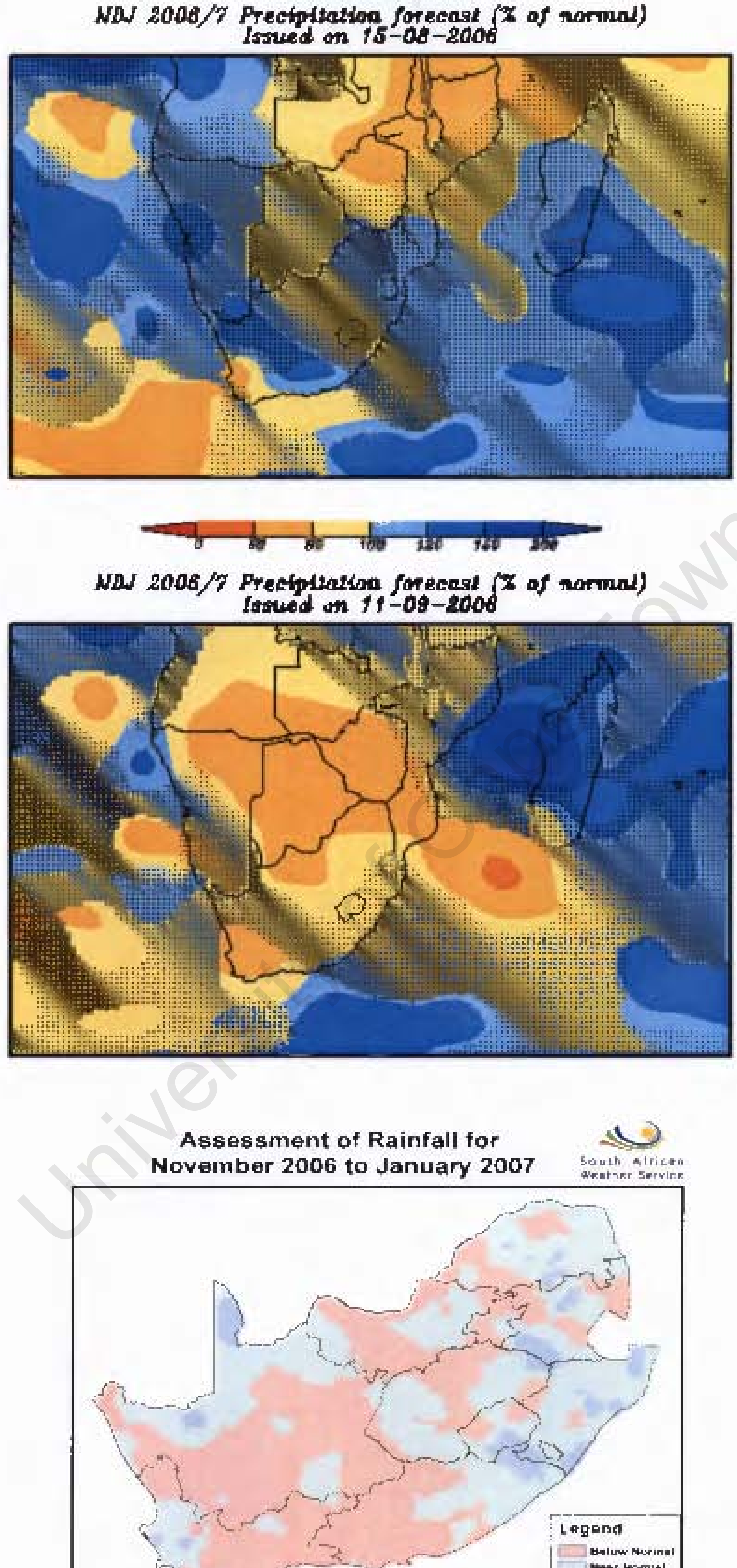


Figure 5.5. The forecast for November/December /January 2006/ forecast in August 2005 and then in September 2005 and the observed precipitation for the same period. (courtesy of SAWS and CSAG)

From a visual inspection the September forecast appears to be more skilful than the August one.

The usefulness of the information contained in the forecast was also clearly useful to the farmers with over 80% finding the information more than *slightly relevant*, while almost 70% maintained that it was *mostly* or *definitely* useful for decision-making.

When questioned about *which* decisions they would use the forecast for, answers were less clear. In the previous survey, taken before the forecast were sent out, there were certain activities (see Table 5.2), for which the forecast was perceived to be useful. When questioned again, a year later, farmers' responses showed a similar response (see Figure 5.6), but very few now claimed to have actually used the information supplied in the forecast to *specific applications* (see Figure 5.7). Although the majority admitted that the forecast information was "useful" and "relevant" and that farm-based decisions were made on the basis on the information, in reality, it seemed that very few were.

This apparent contradiction begs explanation. In the question on which information was used for farm based decisions, the forecast was only one of the available information resources that could impact on the decision.

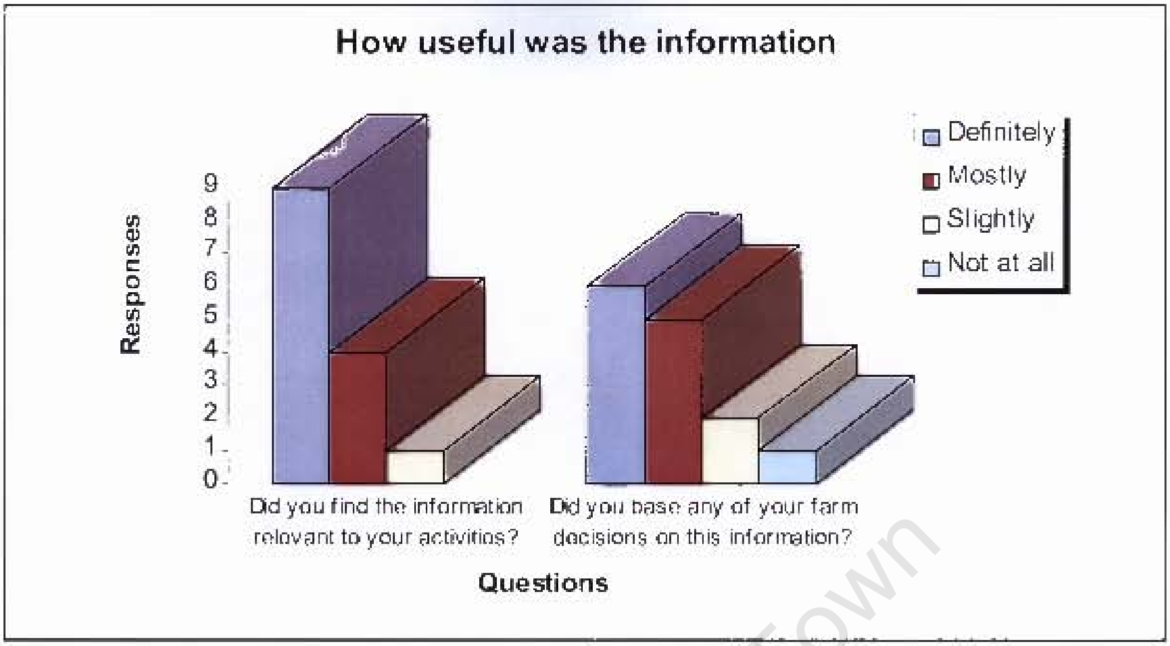


Figure 5.6. General usefulness of the forecast (n=16)

Other information that was named as an important resource for these decisions included:

- Existing weather conditions (see below)
- Current crop prices
- Crop forecasts
- Futures prices
- Farm Cash flow situation
- Soil analysis including moisture levels
- Previous year's crop
- Previous year's yield
- Management capacity
- Research trials results
- Production costs
- Academic advice

- Tradition (based on past practice)
- Computer models
- Seed and fertilizer representatives
- Agricultural media
- Grazing conditions
- Other (older) farmers

From Figures 5.7 and 5.8 it can be seen that the *weather*, as a factor influencing decisions, was given more importance than the climate or weather *forecast* and this raised an important issue. Farmers were interested in the forecast and thought it would be useful, but in the final analysis stated that many of their actual decisions were in fact weather dependent. Most actions were only taken once it was clear that the soil was moist, once the rains had fallen, once the land was ready. A forecast was more useful in the preparation phase, which is reflected in Figure 5.8.

It is not obvious, but still essential to realise that until a forecast is actually verified by actual conditions its benefits cannot be assessed. Some researchers have supported the use of SCFs despite their lack of skill, saying that it may still be some time before the science may be fully advanced (Vogel, 2000; Huda and Packham, 2004)

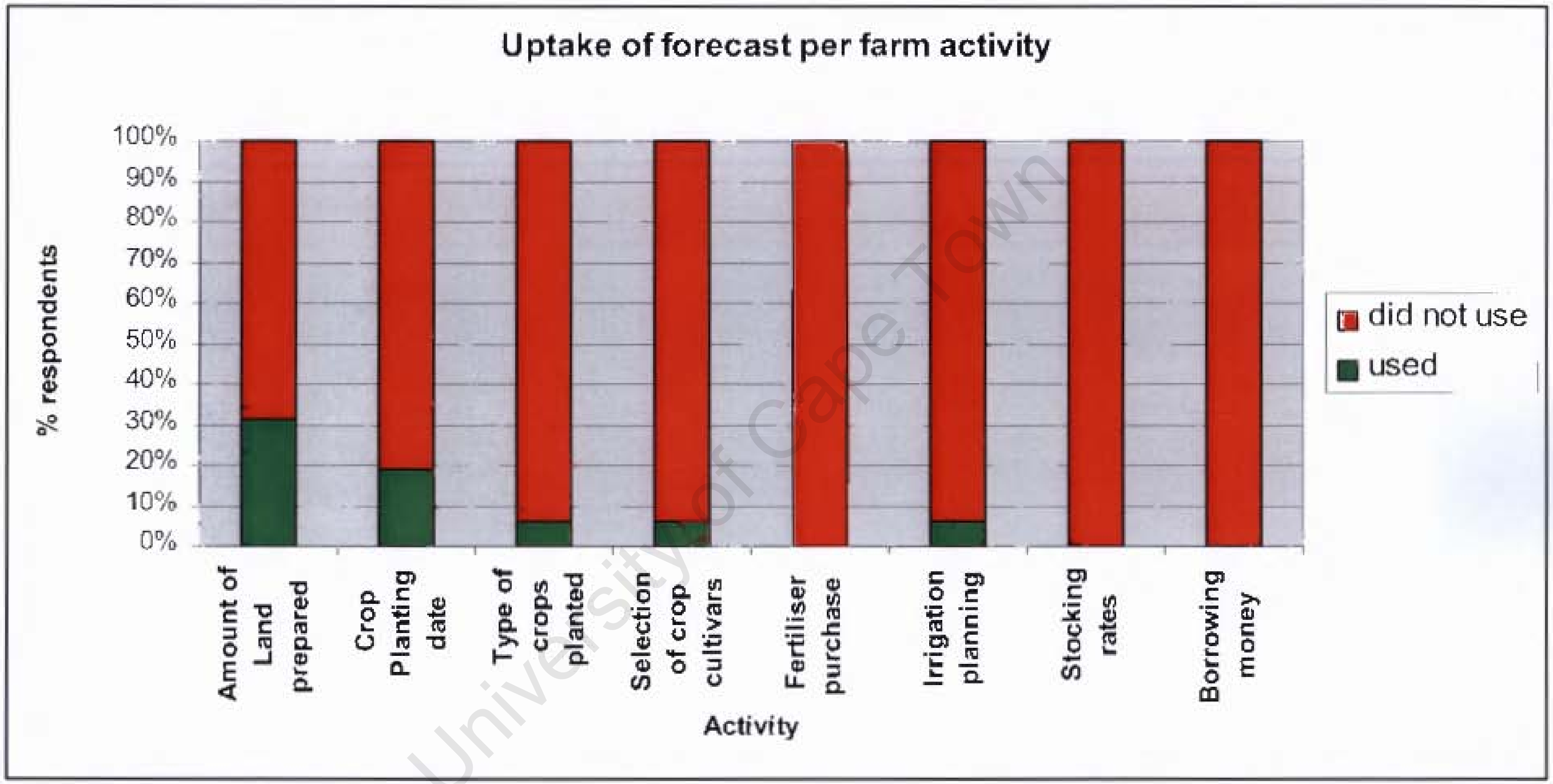


Figure 5.7. ***Specific applications of the forecast***

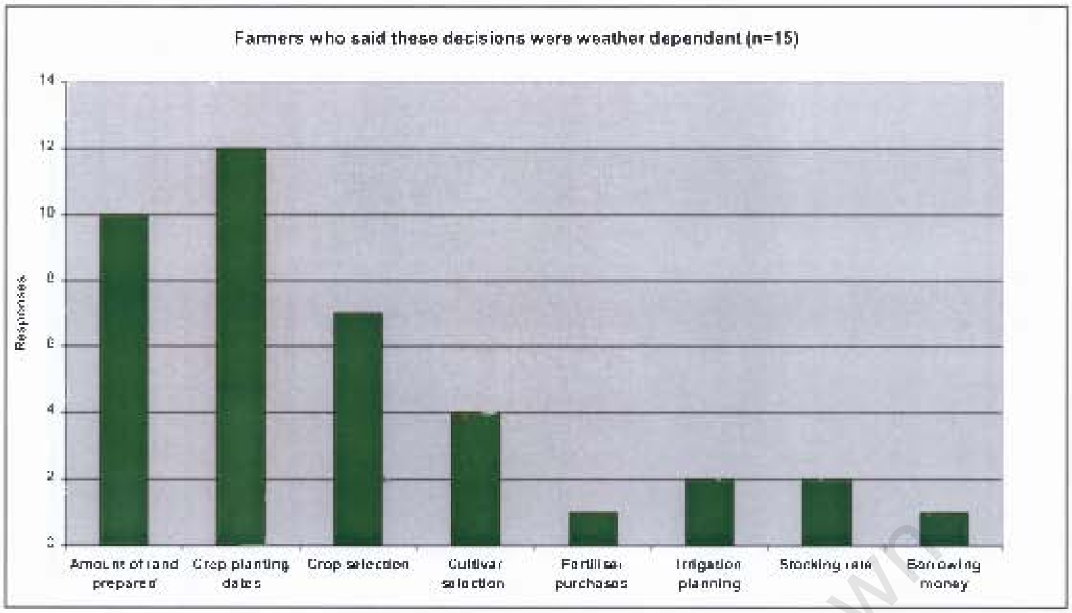


Figure 5.8. ***The weather dependence of specific activities.***

Any farmer would say that his activities were weather dependent – it is one of the 'unknowns', but a forecast should, and often can, reduce the degree of uncertainty, depending on the accuracy and, ultimately, the skill. Thus for a farmer to rate his dependence on the weather is not surprising, but the low dependence on the actual forecast raises the question: *is the forecast a good predictor of actual conditions?* This became the crux of the issue for farmers – each time when they were asked how much validity they would attach to the forecast they would express the opinion that it depended on, and was in strict relation to, the accuracy of the prediction, if not expressed in the forecast by the producers, then from their own experience. Stern and Easterling (1999) stressed the importance of maximising the "ex ante acceptance" of forecasts while minimising the "ex post disappointment" by creating a balance between confidence in a forecast and correct interpretation.

This reflected poorly on the current South African forecast process – that there existed no index or measure of verification for a particular forecast, at a particular time, or for a particular region. Verification schemes were used in the development of the forecasts, in the tweaking and nudging of models during hindcast experiments, but these are not revealed in the release of a product and certainly would escape the comprehension and relevance of most, if not all, users (Doblas-Reyes et al., 2006).

It was decided to develop a scheme of verification for the HadAM3 forecast output for the 3-monthly periods over the period that the forecast had been released for the maize region. The short time that the forecast had been in existence would constrain the validity of the verification, but the aim was to develop a simple scheme that could be understood by users and that would specify skill to a specific area for a specific forecast period based on (an albeit short) historical performance. **It is important to interpret *skill* as used in the following scheme with this limitation in mind**. The statistical validity could be improved by incorporating historical data and hindcasts into the scheme at a later stage – this was not the intention here. It was hoped that this could stimulate the introduction of user friendly verification statistics in issued forecasts.

5.4 A different forecast verification scheme

Joliffe and Stephenson (2003) acknowledge that verification schemes theoretically need to be as simple as possible to facilitate their communication to users, but warns that due to different requirements and interests complexity in methods is unavoidable. (They advocate the consideration of economic factors underlying the users' needs as important when deriving a verification scheme – this was not undertaken here.) An attempt was made here to assess forecast performance based on hits and misses with scores reflecting the degree of miss and hit.

Based on the Heidke skill score (Mason, 2003), without proportion correct adjustment, a formula was developed which measured the performance of a multi-category forecast taking into account the direction and magnitude of the variation in accuracy over the period for which the forecasts had been issued and over the various areas of interest. Although the main focus was the maize growing region (MGR), the W Cape wheat growing areas (WGR) were also included. The formula was applied to the sequential, running 3-month forecasts versus observed rainfall over the period 2003-2006 for 22 rainfall stations distributed throughout the MGR and 16 stations in the WGR (see Figure 5.9). Observed rainfall was compared to the forecast (relative to normal) and categorised according to the percentage anomaly, as used in the forecast predictions.

The forecasted anomaly for the specific stations was taken off the grads map produced by the model. This also immediately threw up a statistical conundrum: the spatial scale of the forecast was not sufficiently fine to be able to distinguish specific stations from one another on a sub-grid level. This highlighted the question of legitimacy in releasing a forecast for use by farmers and the like who are intrinsically involved in sub-grid scale activity and thus would be affected by sub-grid variation. The fact of the matter is that this is the limitation of current seasonal forecasts and they can either be released with such caveats or not at all. For this reason it was assumed that users would expect a forecast to be more general than specific, but would derive value from knowing how it varied in specific regions at specific times of the year. *Although this verification system does not comprise a* *central objective of this research and is not empirically validated, it is included here to illustrate that some of the widely-held criticisms regarding the lack of publication of skill of seasonal forecasts can, in fact, be addressed.*

For each station, the observed rainfalls for the months were summed into 3-month running totals. The variation from the 3 month mean was calculated as a percentage.

$$\text{Observed rainfall variation from mean } \mathbf{V} = [(R_o\text{-}R_m)/R_m.100]\%$$

(where R_o is the observed rainfall and R_m is the mean rainfall)

It is recognised that this leads to a bias of skill in favour of large rainfall areas or episodes, and to the detriment of low rainfall episodes, as anomalies due to one event would be large in the dry season but minimal in the wet season, requiring much larger anomalies to show a similar percentage variation. This was acknowledged as a shortcoming but in terms of the forecasts' usefulness *in the rainy season*, it was overlooked.

The seasonal forecasts were then accessed and the forecast rainfall prediction for the area in which the station fell, compared to the 3-month mean, was identified giving a forecast percentage of the 'expected' rainfall for the station for each 3-month period since the forecasts were issued. The forecast categories are shown below. The percentage of normal relates to the expected variance by differencing it from 100%.

Both observed and forecast rainfall variations (V) are then separately indexed according to the following scale, which is used in the forecast production.

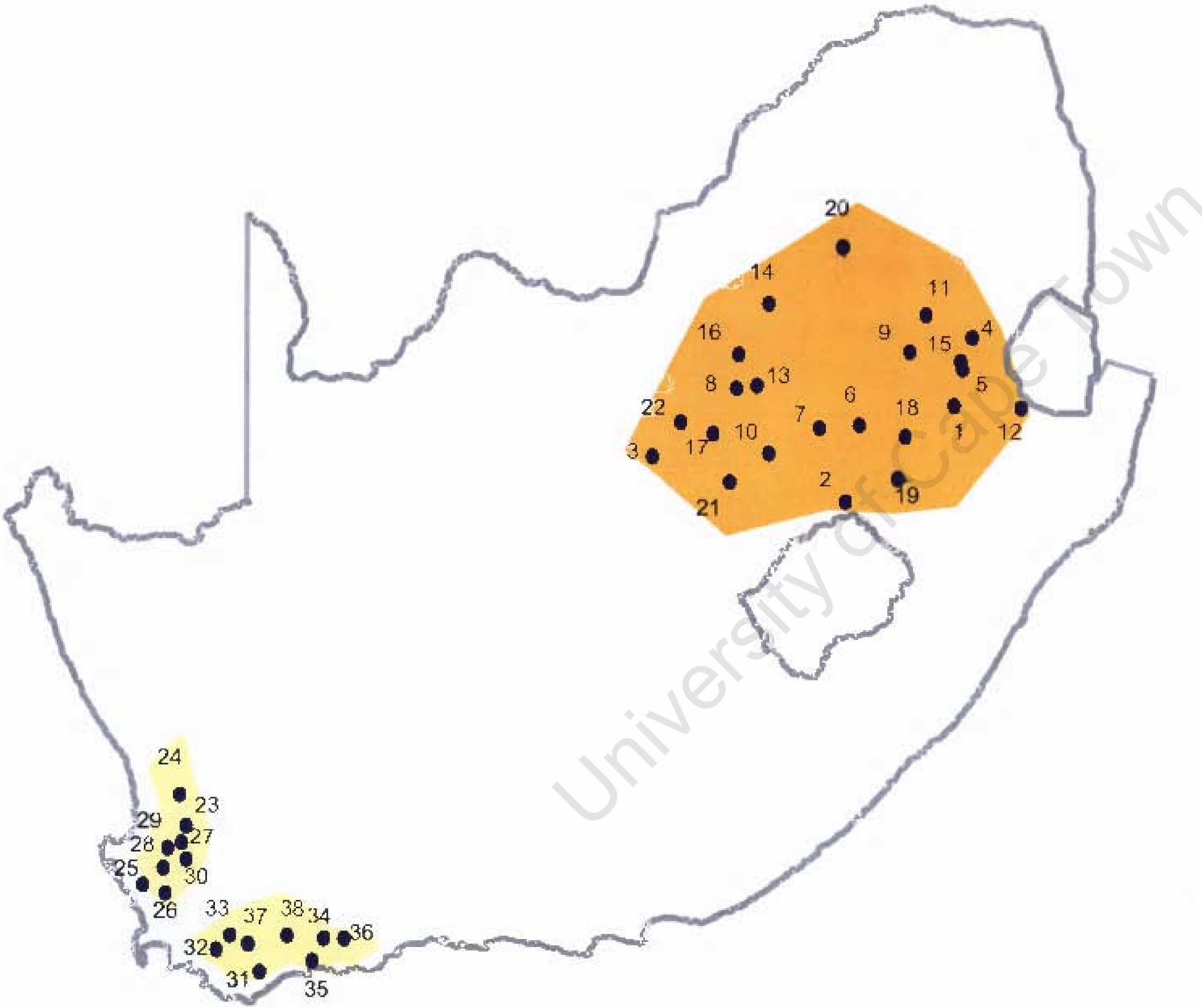
Variation Index	Variation value range (% of normal)
−3	V<−80%
−2	−80%<V<−50%
−1	−50%<V<−20%
0	−20%<V<20%
1	20%<V<50%
2	50%<V<80%
3	V>80%

The Variation Score (VS) is calculated by the magnitude of the difference between the forecast variation index (I_f) and the observed variation index (I_o).

$$\mathbf{VS} = | I_f - I_o |$$

Individual variation forecast scores are then allocated integer skill values according to the score variation, with no, or small, variation incurring positive numbers (2 or 1) and large variation incurring negative values (−1 or −2). An assumption is made that to give very large (>3) Variation Scores of negative magnitudes higher than 2 would penalise the forecast unnecessarily.

Variation Score (VS)	0	1	2	≥3
Individual Forecast Skill Score (FSS)	2	1	−1	−2



Maize Growing region
1 AMERSFOORT
2 BETHLEHEM
3 BLOEMHOF
4 CAROLINA
5 ERMELO WO
6 FRANKFORT
7 HEILBRON
8 KLERKSDORP
9 KRIEL
10 KROONSTAD
11 MIDDELBURG
12 PIET RETIEF
13 POTCHEFSTROOM
14 RUSTENBURG
15 TWEEFONTEIN
16 VENTERSDORP
17 VILJOENSKROON
18 VREDE
19 WARDEN
20 WARMBAD
21 WELKOM
22 WOLMARANSSTAD
Wheat Growing region
23 CITRUSDAL
24 CLANWILLIAM
25 DARLING
26 MALMESBURY
27 MIDDELDEURVLEI
28 MOORREESBURG
29 PIKETBERG -SAPD
30 PORTERVILLE
31 BREDASDORP
32 CALEDON
33 GREYTON
34 HEIDELBERG
35 PORT BEAUFORT
36 RIVERSDAL
37 RIVIERSONDEREND
38 SWELLENDAM

Figure 5.9. ***Location of stations in Maize (1-22) and Wheat (23-38) Growing Regions***

Worked example: Where rainfall was forecast to be between 50 and 80% of normal, and observed rainfall was 60% *above* normal.

Forecast variation index $\mathbf{I_f} = \mathbf{-1}$ [% of normal: $(-50\% < \mathbf{V_f} < -20\%)$]

Observed variation index $\mathbf{I_o} = \mathbf{+2}$ $(50\% < \mathbf{V_o} < 80\%)$

The **Variation Score (VS)** = $|\, I_f - I_o \,| = |(-1) - (+2)| = \mathbf{3}$

The Individual Forecast Skill Score = −2, which, on a scale of −2 to +2, (where +2 is near perfect skill) would indicate near perfect *negative* skill – the negative value would serve to lower the total forecast skill score.

The variation caused by numerous inaccurate forecasts would negate any gains from accurate forecasts when summing the Individual Forecast Skill Scores (FSS) to attain the Total Forecast Skill Score (TFSS).

$$\text{Total Forecast Skill Score (TFSS)} = \quad \Sigma \text{FSS}_{(t,r)}$$

(where t is the season or part of the season for which the forecast is issued, and r is the station where the forecast is applicable)

The Forecast Index (FI) is the average TFSS for the region and season on a scale of −10 to +10, where −10 reflects negative skill and + 10 perfect skill. FIs are calculated for specific areas in specific seasons to ascertain where and when the forecasts had most skill and could most usefully be applied.

$$\text{FI} = \frac{{}^{s,n}\Sigma\ \text{FSS}.10}{2n.s}$$

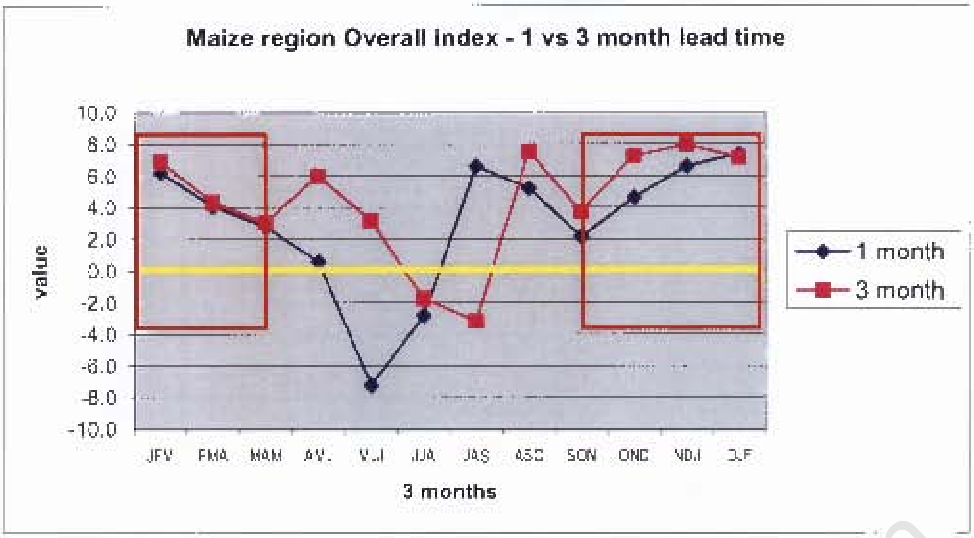
(where n is the number of stations contributing to the region and s is the number of seasons for which forecasts were produced. The '2' in the denominator reflects the maximum possible (or perfect) FSS value that can be obtained, based on the table above.)

Results from the study areas give forecast indices for each 3 month period during the year for each area and, in the case of wheat, the 2 sub-areas of the WGR, the north-west *Swartland* and the south west *Rûens* areas.

Forecast Index	Lead Time	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ	DJF
Average for 2 regions	1 month	4.9	4.4	2.2	0.4	-3.2	1.2	6.1	4.8	2.9	3.0	5.0	5.2
	3 month	6.1	4.7	3.2	4.7	3.1	0.3	1.9	4.7	6.3	4.9	5.5	4.8
MGR	1 month	6.2	4.1	4.2	0.6	-7.2	-2.8	6.1	5.5	3.3	4.2	6.6	6.9
MGR	3 month	[illegible]	6.5	4.5	6.3	3.2	-2.6	0.3	[illegible]	7.6	6.4	7.5	6.7
W Cape WGR	1 month	3.0	4.8	-0.6	0.1	2.3	6.7	5.3	3.9	2.3	1.4	2.7	2.8
W Cape WGR	3 month	4.9	2.3	1.3	3.0	3.0	4.2	4.1	4.4	4.1	2.8	2.7	2.2
W Cape-East	1 month	1.3	3.5	-0.9	0.8	5.0	7.3	[illegible]	2.7	2.7	-0.4	-0.8	-0.2
W Cape-East	3 month	3.3	1.6	0.3	1.7	4.2	4.4	1.3	2.3	5.0	-0.4	1.5	0.0
W Cape-North	1 month	5.8	6.3	-0.3	-0.6	-0.4	6.0	7.9	5.0	1.9	3.1	6.3	5.8
W Cape-North	3 month	[illegible]	3.1	2.2	4.4	1.9	4.7	6.9	6.5	3.8	6.0	4.0	4.4

Table 5.5. *Forecast Indices for the MGR and WGR for successive 3-month periods. Shading indicates key level of skill (Green >4, Orange <0, and red <-5)*

For a Forecast Index skill to be valuable, it was estimated that an index of +4 and above (or 70%+ skill) would be useful for users. The forecasts that attained this value or more would be disseminated while forecast achieving lower scores would not. It was tempting to disseminate negative scores with the caveat that they were ***highly unlikely*** to be accurate, and in this way indicate that in fact a negative skill could be attached to them.



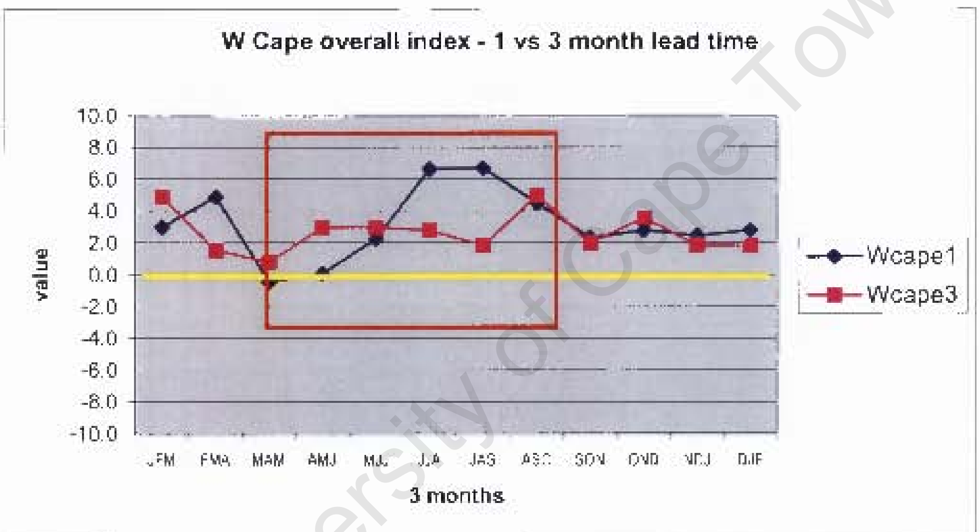


Figure 5.10. ***Graph of forecast skill indices for the maize and wheat growing regions for 1 month and 3 month lead times, showing the rainy season inside the red box***

The table of FI values above and the graphs in Figure 5.10 show that the forecast could certainly be regarded as having skill in the maize growing region (MGR) during the growing season (taken over the short sample record), which is when it would be most useful, according to the data collected from all the farmers. With one exception, all the forecasts issued between August and March showed skill levels of more than +4. This infers that the forecast was (and perhaps *could*) be correct 70% or more of the time, or more candidly, 7 times out of 10. The skill in the WGR is more discernable during the winter rainfall season. The possibility of the apparent skill being attributable to random noise was not investigated, but deemed unlikely, considering previous verification during the development of the model.

It is also of interest to see that the forecast with 3-month lead time, in more than a few occasions, had more skill than the one with a 1-month lead. This can possibly be explained by a lag in atmospheric response to sea-surface temperature changes.

These FI values were added to the forecast bulletin from November 2005. After consultation with farmers it became clear that more value could be added by giving the implication of the forecast on actual rainfall figures in terms of the normals. This indicated a willingness by farmers for interpretation of the forecast to be applied *for* them, on the basis of their individual rainfall figures. What was required was an idea of what a forecast of 50-80% of the normal rainfall actually meant in their region. It had already been observed that a significant number of farmers overestimated their average rainfall, associating *normal* rainfall with *good* years (Daly, 1994).

Table 5.6 shows that farmers already recorded and used rainfall data to assist them in finding analogue years. By applying these values to a probabilistic forecast category they would be able to estimate the rainfall range according to their unique microclimate.

Length of rainfall record				
years	0-5	6-10	11-20	21-50
Number of farmers n=19	3	0	2	9

Table 5.6. *Number of farmers with rainfall records that they used to assist them.*

To facilitate the correct interpretation, it was decided to apply the forecast percentages to the normal rainfall for the stations in the MGR to create a range of seasonal rainfall expected for the applicable months where the forecast indices showed skill of above +4 (see Box 5.1).

The method employed was to extract normal rainfall figures from the SAWS database and apply the probabilities given by the seasonal forecast to the 3-monthly totals, giving a range of rainfall values corresponding to the percentages provided by the forecast. E.g. if the normal rainfalls for Sept, Oct, Nov for a station are 110, 120 and 130 mm respectively, then the normal SON rainfall would be 360mm. If the forecast predicted 80-100% of normal rainfall for that period, it would be reasonable to expect between 80-100% of 360mm, viz., 288-360mm.

The feedback from farmers indicated that the 3-monthly total was helpful as a seasonal guide but, for most of their operational purposes, *monthly* predicted rainfall totals would be more useful. The analysis of individual monthly forecast skill was not attempted, but based upon the assumption that the skill during the growing season would be similar to the 3-monthly skill indices, it would be possible, when an analysis confirmed this, to produce ranges of rainfall for each of the months included in the 3-month season. It must be remembered that monthly forecasts are currently issued by SAWS and other institutions, but only for one month lead time (see Box 5.2).

CSAG FORECAST SKILL
on a scale of −10 (negative skill) to +10 (perfect skill).

For the summer rainfall region, (SRR) since inception:
ASO forecast skill = +5.5

Individual station means and projected rainfall for August/September/October, based on the CSAG forecast

1. **AMERSFOORT**

	Normal	Projected
AUG	11.6	
SEP	27.4	
OCT	82.6	
mm	121.6	146-181

2. **BETHLEHEM**

	Normal	Projected
AUG	26	
SEP	30.8	
OCT	79.8	
mm	136.6	165-206

4. **CAROLINA**

	Normal	Projected
AUG	8	
SEP	22.7	
OCT	99.2	
mm	129.9	156-195

8. **KLERKSDORP**

	Normal	Projected
AUG	6.4	
SEP	15.5	
OCT	53.8	
mm	75.7	91-114

16. **VENTERSDORP**

	Normal	Projected
AUG	6.2	
SEP	17.7	
OCT	56.3	
mm	80.2	96-120

17. **VILJOENSKROON**

	Normal	Projected
AUG	7.8	
SEP	16	
OCT	61.6	
mm	85.4	102-128

10. **KROONSTAD**

	Normal	Projected
AUG	10.2	
SEP	7.3	
OCT	54.4	
mm	71.9	86-108

Box 5.1. *An example of projected seasonal rainfall totals where the forecast for the region was for 120-150% of normal rainfall*

For the summer rainfall region, (SRR) since inception:

DJF forecast skill = **+6.9**

AMERSFOORT

	Normal (mm)	Forecast % of normal	Projected (mm)
DEC	112.2	80-100	90-135
JAN	115.2	50-80	58-92
FEB	86.2	50-80	43-86
DJF mm	**313.6**		**250-314**

The ranges shown are reflected by each separate forecast and will not always agree in total with the 3-month average. These are guidelines, based on the forecasts.

Box 5.2. *An example of projected monthly rainfall totals using individual monthly predictions*

5.5 Feedback and reflection

Further feedback from farmers has been positive but not particularly encouraging – the 3-monthly forecast totals have yet to prove useful in practice as they essentially convey the same message as the general forecast (below normal, normal, above normal). The major requirements for a forecast from farmers have always been spatially and temporally accurate rainfall predictions at least 1 month in advance. It is not clear whether the detailed prediction included in the above tailored forecast product meets these requirements. In many cases farmers still showed that they were more able to benefit from *reactive* actions once weather conditions had manifest themselves, than by *proactive* actions based on a forecast with untested skill and relatively low spatial resolution. For the purposes of this study it is however the best possible beneficiation of forecast data available.

The forecast verification scheme was not tested on a large group of farmers as it was not possible to produce data for a statistically significant period, but sampling of their responses assisted the forecast format to evolve as it did. The verification scheme was introduced and used to assist water resource managers during a separate survey in 2006/7 and is used in an interactive website to interpret seasonal forecasts in terms of expected rainfall ranges. (See www.C4W.org.za)

In chapter six the impact of forecasts on farm-level decision-making and the managing of risk will be investigated, leading to overall conclusions regarding the usefulness of seasonal forecast information.

Chapter 6: Cognitive decision making processes regarding seasonal forecasts and maize farming

"No-one can predict the weather – only God knows what will happen"

"I am a maize farmer, not a financial analyst"

"You can only expect a forecast to be right about 20% of the time"

Some responses from farmers to the question: "How useful are seasonal forecasts in your decision making?"

Decision-making in the agricultural context can be enhanced by using climate forecasts, provided, as has been seen, that a prior understanding of the users' situation and needs has been taken into account. These requirements have been enumerated at many workshops, in the literature and by word of mouth. When the aims of the forecast producer are aligned with the requirements of the user and if the problems of bias and ambiguity are be addressed, then the uptake of forecasts will be greatly enhanced. However the way that the forecast user regards, comprehends and acts on the forecast depends on many factors. In the previous chapter an attempt was made to convey the concept of skill of forecasts and how it varies temporally and spatially and how farmers viewed them in that light. The responses showed many potential advantages of seasonal forecasts, but were not convincing in terms of the acceptance and application by users.

This chapter addresses the cognitive decision making processes involved in commercial maize agriculture vis-à-vis the forecast and investigates whether seasonal forecast information is, in fact, cumulatively useful. The element of risk and its relationship with agricultural decision-making and the impact that seasonal forecasts have will also be addressed.

6.1 The meaning of probability

The value of probabilistic forecasts generally has been shown to be equal to or greater than the value of deterministic forecasts for all users of such forecasts (Murphy 1977; Krzysztofowicz, 1983). But, as mentioned in chapter 3, the decision–maker finds himself facing a quandary: the likelihood of one event occurring is greater than another but there is still a possibility of the less likely event occurring. Having been told that there is always uncertainty inherent in a forecast, the user must now decide how to interpret the probabilities. How closely does 60% chance of above–normal rainfall represent a 'likely' outcome of that nature?

From the analysis of farmers understanding of forecasts and the jargon attached to them, it was evident that there was a level of key misunderstanding. In Table 6.1 the response to the understanding of 60% chance of rain revealed a lack of clarity while a tercile probability scale of seasonal rainfall showed that probability is widely misunderstood. Similar results were found by Hartmann et al. (2002) in the southwest USA.

Piattelli-Palmarini (1994) is quoted in Nicholls (2000): "Any probabilistic intuition by anyone not specifically tutored in probability calculus has a greater than 50% chance of being wrong". The question that arises is one of confidence and uncertainty. Is it possible for a forecast to contribute to the decision-making process of an individual if doubt and uncertainly exists in that individual with regard to the forecast (Webster 2003)?

How do you interpret a 60% probability of rain over a period?	**No of respondents n=52**	**%**
Excellent chance of rain	8	15
Good chance of rain	11	21
Possible chance of rain	28	54
Not sure	2	4
If a seasonal forecast declared the probabilities of above-normal/normal/below-normal rainfall as 30/50/20, what would you expect?	**No of responses n=52**	
Good chance of normal rainfall	4	8
Average chance of normal rainfall	34	65
Not sure	12	23

Table 6.1. *Responses from targeted and non-targeted farmers on interpreting probability.*

In this context it becomes clear that all the subsequent decision-making influences rest upon an understanding of probability. In one exercise with farmers, the author used an opaque bag containing pieces of paper representing normal (N), above-normal (AN) and below-normal (BN) rainfall seasons, rearranging the numbers of each possibility according to an arbitrary forecast. For example, if the forecast was for AN/N/BN::50/30/20, then there would be 10 pieces of paper; 5 of AN, 3 of N and 2 of BN. For a single season one piece was randomly drawn out of the bag. If it happened to be a BN, the surprise and indignation (or resignation) of the audience was immediately apparent. Disparaging comments regarding the skill of the forecast would be made.

In such an elementary demonstration it would seem that there is no skill, only luck – it takes some concerted education to demonstrate that the skill lies in being able to attach higher or lower probabilities to certain outcomes based upon scientifically proven signal detection and knowledge of atmospheric dynamics. Farmers also revealed a personal interpretation of probability, depending on the source. Often they would recall that if one source said X% then the chances of rain were Y%, but if another source said X% then the real chances of rain were substantially more (or less).

In work done by Sherrick et al., (2000), the commonly used assumption that decision-makers possess accurate prior probability information about climate events that affect them, especially in terms of producing a living, was investigated. The impact of that assumption on the valuation of prediction information showed that producers systematically misrepresent the probabilities of climate events that materially affect their well-being. The most common form of the contrast between actual and subjective probabilities was the *overstating* of the likelihood of adverse events and *understating* the likelihood of favourable events. This inherent pessimism, whether genuine or not, was reflected in some comments by the subjects of this research, viz., “sceptical of forecasts”, “previous year was bad, so expecting the same this year”, “the rain doesn’t come like the old days” as well as those quoted at the beginning of the chapter.

It may be that this is a form of preparedness to counter climate dissonance. If decisions were made that subsequently were shown to be wrong, the negativity expressed prior to the event would be justified by the outcome. This reaction will be explored further.

6.2 Interpretation of information

Bert et al., (2006) stipulated five conditions that defined useful forecasts. The information provided needed to be relevant to, and compatible with production decisions. It also needed to provide various decision options that would result in different outcomes depending on the climatic conditions. Thirdly, the user needed to be able to evaluate the outcomes of the alternative outcomes resulting from their decision. Fourthly, the forecast needed to have 'useful' accuracy and 'appropriate' lead-time. Finally decision-makers needed to be willing and able to modify their actions in response to the climate information they received.

The first two conditions are pertinent here. Is the information in a seasonal forecast *relevant* and *compatible*? Can it then provide decision options depending on the variation of its content? Nicholls (2000) emphasised that the value of seasonal forecasts lies not only in accuracy, but also in their ability to allow management options which farmers could use to take advantage of the forecasts. The effective interpretation by farmers would necessarily depend on the answers to these questions. A simple example was revealed when farmers were questioned about the profit/loss relationship with the actual rainfall in a prior year.

Asked whether their farm had made a profit, loss or broke even, whether they had experienced, in their opinion, normal or above/below normal rainfall, and whether their own farm had received the same, more, or less rainfall than the surrounding district, the answers were analysed to reveal the discrepancy between the perceived correlation of rainfall, yield and profit. A cross check with their answers and the measured district rainfall led to the first observation; that farmers did not always understand what 'normal' rainfall meant, significantly over- and under-estimating the values. It was more common to estimate their normal rainfall value to be higher than the historical record – this naturally led to the impression that the rainfall received was below normal, when in fact from a meteorological perspective it was normal or even above normal.

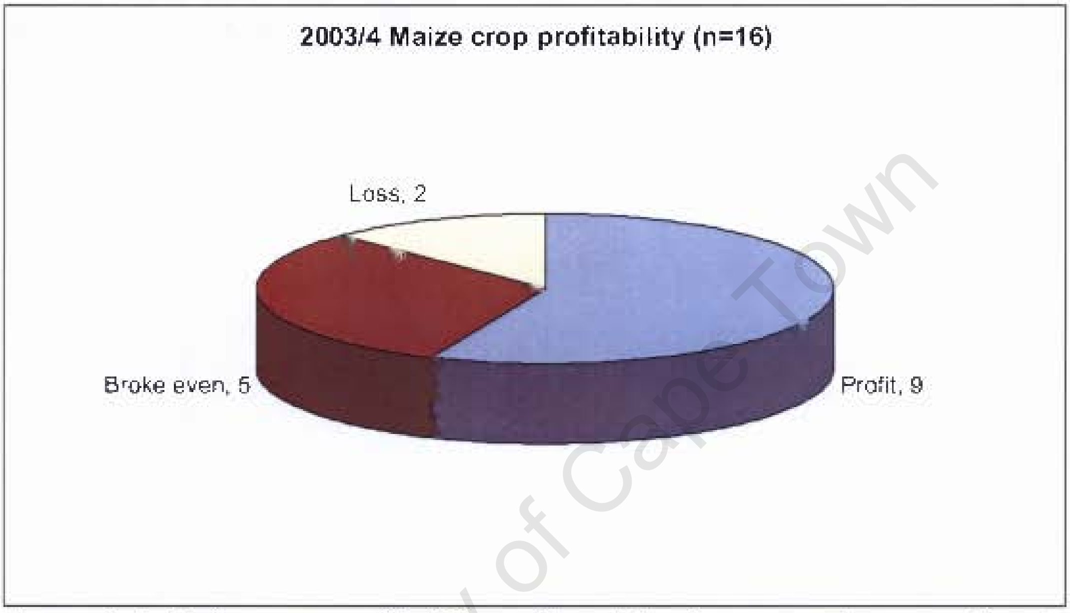


Figure 6.1. ***Maize crop profitability reflected by the targeted group of maize farmers***

When farmers had had a profitable harvest, they tended to regard the rainfall received as normal or above normal. 56% of surveyed farmers made a profit in 2003/4, and, of these, 77% said that the rainfall had been normal or above normal. All said that their rainfall was the same or higher than the district average. These results may appear obvious. If the rainfall was in fact above average, then a profitable crop would surely follow.

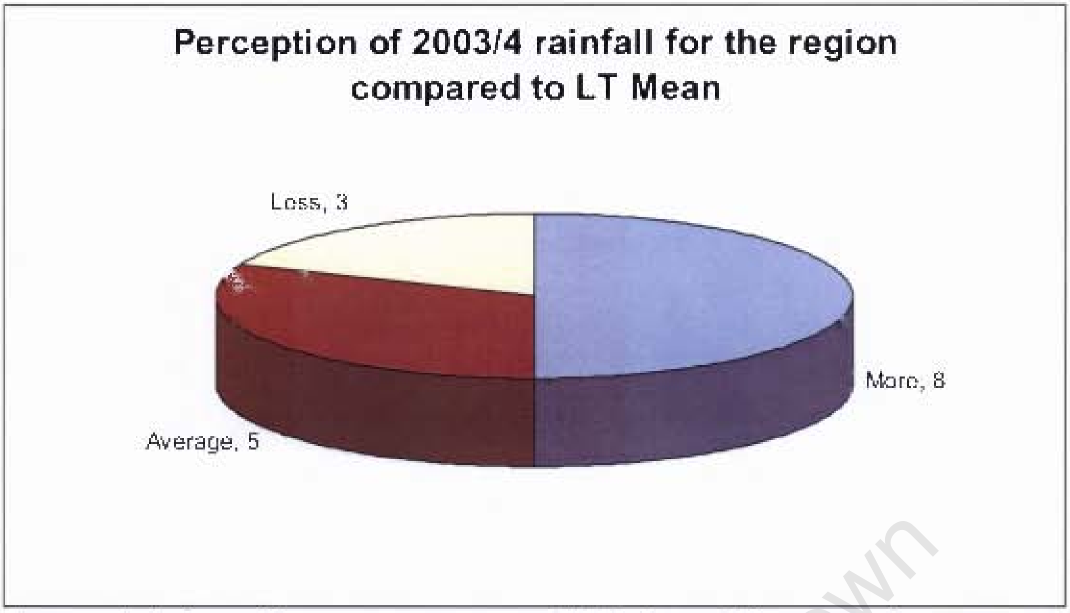


Figure 6.2. Solicited farmer's perception of 2003/4 rainfall compared to mean

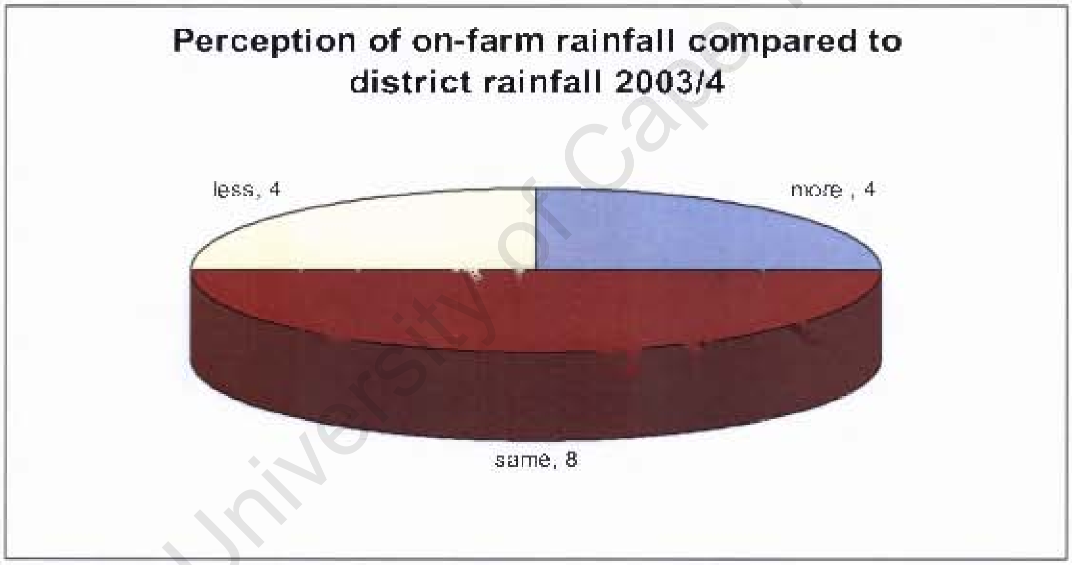
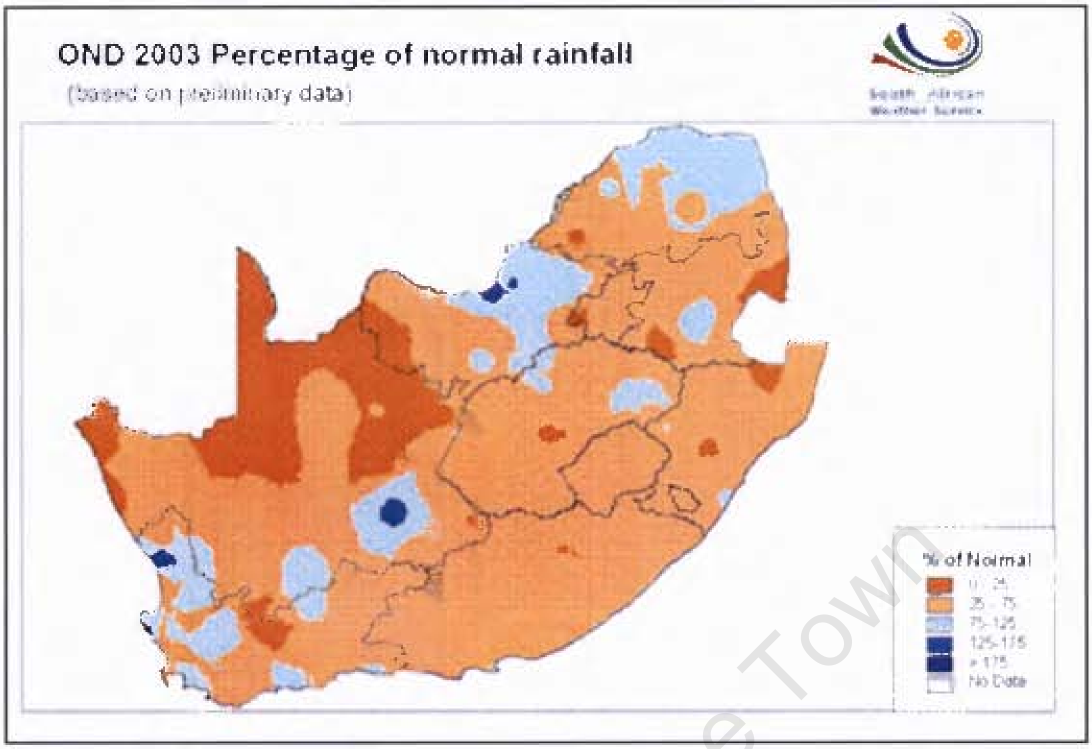


Figure 6.3. Solicited farmer's perception of 2003/4 rainfall compared to district

However, 12% experienced a loss and both stated that their rainfall had been less than normal, and the same, or less, than the rest of the district.



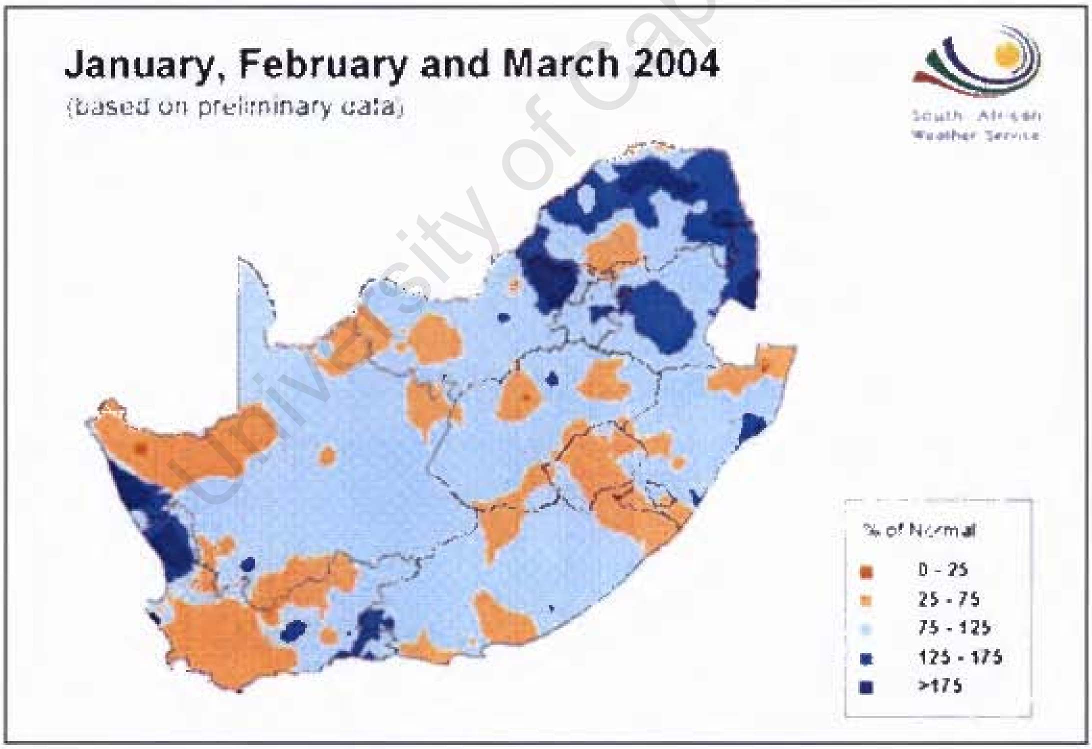


*Figure 6.4. **Observed rainfall over SA during October/November/December 2003 and January/February/March 2004 (courtesy SA Weather Service)***

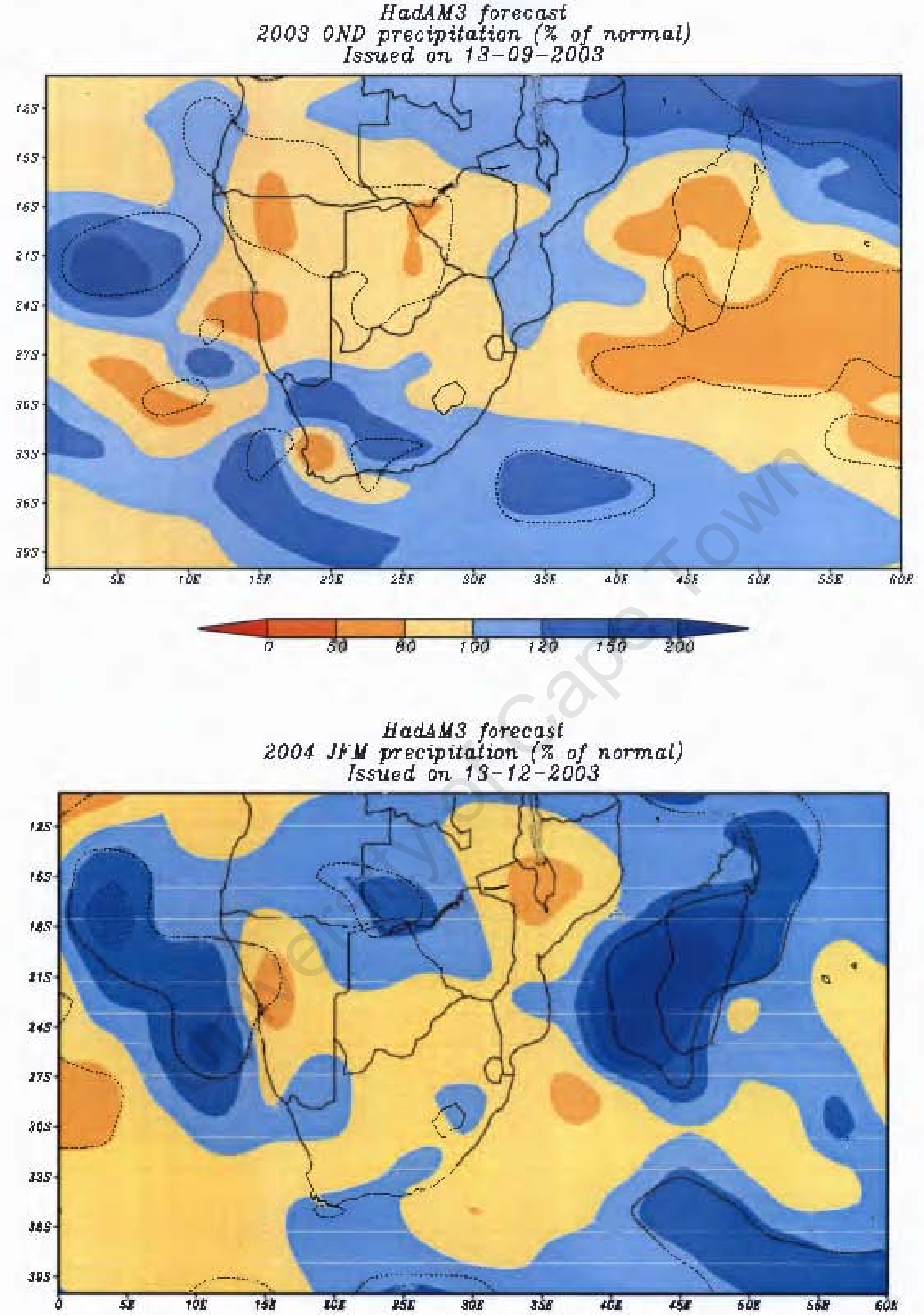


Figure 6.5. ***Predicted rainfall over SA for October/November/December 2003 and January/February/March 2004 (courtesy of CSAG, University of Cape Town)***

While accurate rainfall figures for the specific farms were not available, from the station data, the entire region had experienced between 30-80% less rainfall than normal during critical months early that season (OND), but almost all stations reported higher than normal rainfall in the JFM period. The issued CSAG forecast for the season had varied between 80-120 % of normal rainfall and had not predicted the late onset of rains, which only arrived in January. (Refer to SAWS rainfall maps in Figure 6.4 and the CSAG forecasts in Figure 6.5)

These data, albeit from only one year of observation, serve to support both the contention that the forecast cannot necessarily predict farm scale rainfall accurately, and also that individual farm level decisions and actions are as important in achieving profitable yields. It must be considered that a good yield does not necessarily lead to a profit, as during drier periods the price increases and farmers who lock into higher priced contracts during such dry periods can achieve higher returns than those who delay their contracts to a time when rainfall has increased, with consequently lower prices. (See discussion in chapter 7 in this regard.)

Interestingly, of the farmers who admitted to not taking the forecast into account (25%), none reported achieving a profit that season.

It was clear that farmers who used the forecast were however still sceptical – none were willing to credit the forecast with their success, though 78% said they believed it, with 23% stating it had been consistently accurate and 53% saying it was partially accurate. The balance of 24% said that it was not at all accurate.

The relationship between the farmers' attitudes *before* the forecasts were sent to them, and the attitudes *after* they had received them for a year is interesting (see Table 5.4). The relative average value of the relevance of the forecast increased over the period, but the overall usefulness was statistically significantly less. This will be discussed further later.

Farmers initially believed that the forecast could assist them in their decision-making and planning; however it remained unclear whether the forecast proved useful during this particular season – it was essentially correct in predicting drier than normal conditions, but omitted to capture the late onset and consequent significant dryness of the early season.

In 2006 a report appeared in a South African agricultural journal, reflecting the views of 3 different types of forecast producers. The first was a weather prophet, the second the author of Maize-vision, an ENSO oriented forecast publication and the third a forecast producer from the South African Weather Service. It is interesting to look at how the information is expressed, what certainty is offered and what conclusion an end-user may draw through it. Certainly it is very apparent that the forecasts are much generalised, in some cases prefaced on what has already happened, and on the ENSO index, while in another the influence of ENSO is denied.

Beneath the article is a map showing the observed rainfall for the January/February/March period that followed (Figure 6.6). It is not a trivial exercise to decide which forecast author was correct (although the weather prophet was clearly less accurate) as the forecasters are less than forthright about specific outcomes. Such is the nature of a neutral season forecast, that skill is unlikely to be high.

6 January 2006

Weather prophet sees drought

The "weather prophet" Prof. Peet Pienaar predicts a dry, hot summer in the summer rainfall region for the coming months.

"Nothing will be normal. It's going to be very hot and dry, and the wind direction will be wrong," he said. "Things are not looking very good if I look at what nature tells me."

He expects storms and hail damage when it does rain.

Dry cycle lasted for at least 4 years

It is an indisputable fact that South Africa has been in a drying cycle for at least four years.

Mr. Johan van der Berg, weather expert at Agricultural Research Council in Bloemfontein, says that in the last eleven years only three years were characterised by above normal rainfall.

Soil moisture conditions have worsened dramatically especially in the past four years on account of below normal rainfall.

Good harvests have been collected because it has rained at the rights times in the growing season. The showers have been however just enough to allow plant growth, but not enough for run-off and infiltration, he said.

Although it difficult is to predict when a dry cycle will end, the country is, according to one model, now about at the middle of the present one.

Van der Berg also shows that that a dry cycle does not inevitably just include dry years. Usually there are also three to four wet years in such a period.

Regarding this summer, the chances are almost 100 % that neutral conditions will continue, based on the southern oscillation index (SOI) and sea temperature analysis in the Pacific Ocean. (This index is an indication of the El Niño and La Niña phenomenon.)

Van der Berg says the SOI has been neutral for the past few years, and the chance of an El Niño or La Niña before March or April is almost nil.

Long range forecast

Dr. Willem Landman of the South African Weather Service's long range forecasting group warns however that it is a mistake to expect South Africa's rainfall to be average because conditions in the equatorial Pacific ocean are neutral.

"To tell the truth anything in South Africa is possible with such a state. We can well expect that El Niño or La Niña and their related conditions will not influence our weather for the rest of the summer," he said.

Landman says that temperature patterns of the sea-surface around South Africa are not really indicative of what can be expected for the season. Forecasters therefore are being guided by the consensus based on forecast models. These models' message is that the south westerly and north easterly parts of the country stand the biggest chance of receiving low rainfall figures.

The chances of high rainfall nationwide appear to be very slim, says Landman. There is however a chance that the central interior and the adjacent coastal regions could receive their normal rainfall quota.

After the summer rainfall season ends in April, the north eastern parts can expect below normal rainfall. The expectation of favourable conditions in the central areas will however continue. For the south westerly parts below normal rainfall conditions are most likely, said Landman.

***Box 6.1.** Excerpt from article in Landbouweekblad 6 January 2006 (Coetsee, 2006)*

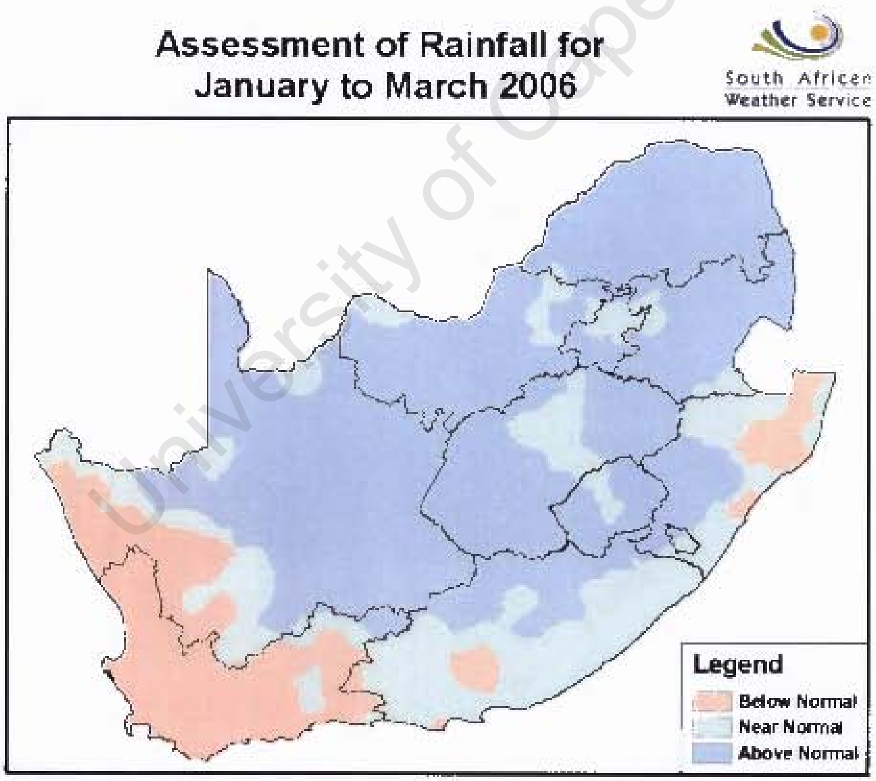


*Figure 6.6. **Observed rainfall for the January/February/March 2006 period (courtesy of SAWS)***

6.3 Climate/weather risk and agriculture

It is obvious that agriculture is to a greater or lesser degree highly dependent on weather. Without sunlight and water few crops would survive. In the case of maize, most crops are rain-fed and thus more dependent on the direct effects of the weather and climate than those which can rely on irrigation. When asked about the risks facing them, the farmers all named the weather as the main risk. It is pertinent to note that the Afrikaans word *weer* (literally translated as 'weather') was used to represent the seasonal climate as well. None of the farmers used the term *klimaat* (climate), instead using *weer*, indicating that the word may well represent the whole seasonal temporal range of rainfall.

Although rainfall was the main concern, at various critical points during the growing season heat, wind, hail and frost were all risks that would impact on, if not devastate, the crop. All farmers named market prices as another risk, while labour laws, politics and input costs were named by about half of the respondents. One named fire as a risk, but remarked that it was rare.

In Table 6.2 below, the decisions that were dependent on each risk factor are presented.

In terms of signals that would influence a forecast, the most obvious would be changes to sea-surface temperature regimes. When a signal is detected and fed into a climate model, the results will usually show the direction of any tendency toward

RISKS DECISION	Weather	Market Price	Labour laws	Politics	Input costs
Crop type					
Cultivar choice					
Planting date					
Amount planted					
Livestock purchase/disposal					
Row width/plant density					
Financial options – hedging					
Fertiliser amounts					
Hiring of labour					
Soil preparation					
Fixing of contracts					
Marketing strategy					
Capital expenditure					
Pesticide amount/ weeding strategy					
Daily planning					

Table 6.2. *The major risk factors in maize farming and decisions that depend on the nature of the risk*

a seasonal rainfall change. The forecast will reflect this in monthly and 3-monthly rainfall totals, but an average over the period will seldom indicate an earlier or later onset of rains. As seen in chapters 4 and 5, this is one of the outcomes most sought after by farmers. It is widely acknowledged (e.g. Carberry et al., 2000; Carter et al., 2000) that the value of a seasonal forecast, however good, depends on the circumstances and, especially, the risk preferences of the decision maker and this will emerge further below.

6.4 Making relevant decisions

Bert et al., (2006) created decision maps that showed pathways of decision sequences, resulting in different actions, depending on different climatic (and other) scenarios. The actions and pathways coincide with the results obtained from the surveyed farmers in terms of the assignment of land, type of seed and amounts of fertiliser applied.

In the diagram below, the decision path begins with a specific selected decision that needs to be made, in this case the assignment of land for maize. The decision depends on some uncertain variables, such as future rainfall or soil moisture, as well as some known (or deduced) variables such as soil moisture. Other variables that can be influenced by user action depending on the requirements, such as fertiliser, do not come into the decision path at this stage.

Depending on the information obtained from climate forecasts (and how they are interpreted), the decision path moves towards a specific option, increasing, decreasing or maintaining current land allocations. The decision path is then repeated for each decision such as sowing date, the type of hybrid seed, fertiliser management and planting density.

In this example in the Argentine Pampas region the impact and influence of El Niño/La Niña signals was deemed to be 'strong' with a correlation between warm

ENSO and wetter conditions, and cool ENSO and drier conditions. Maize yields in the region also showed a close association with the ENSO signal. It has been shown (in Chapter 3) that the correlation for the South African maize growing region (MGR) is not as high, and consequently a decision path for South Africa would be less ENSO dependent.

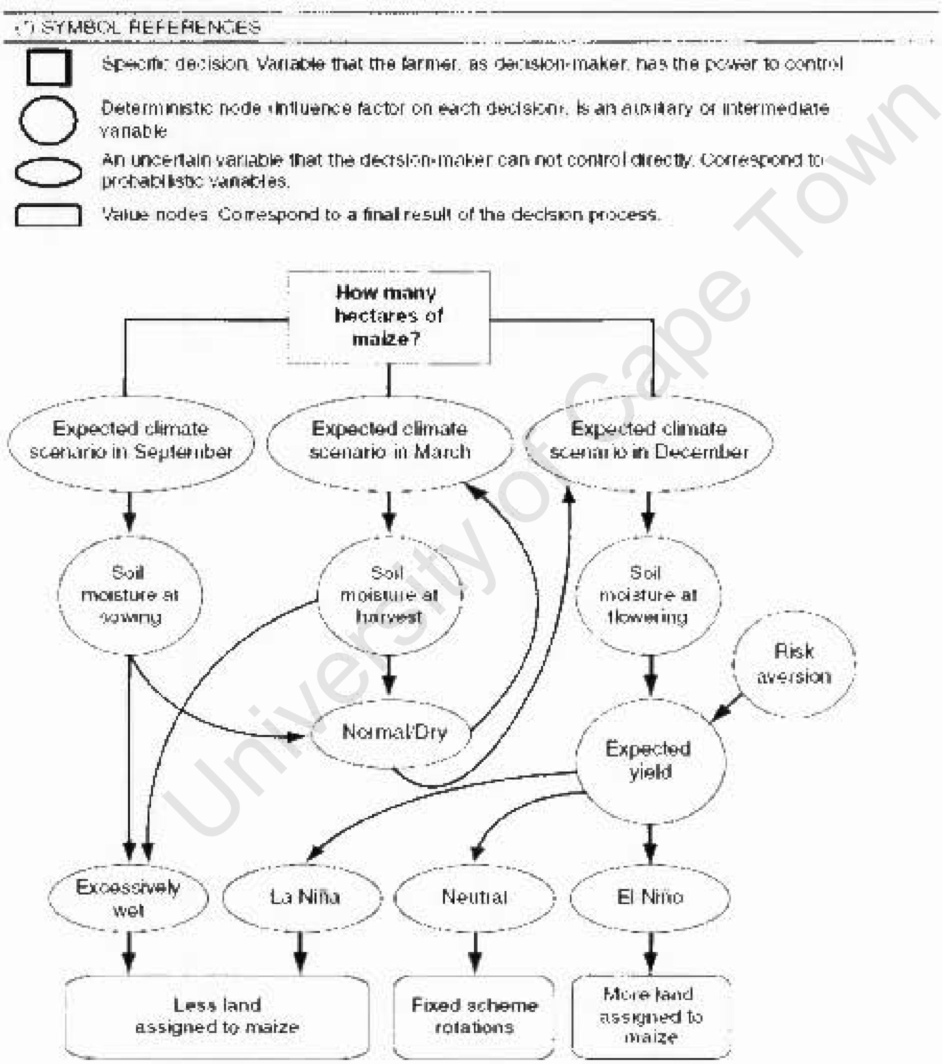


Figure 6.7. ***Conceptual representation of climate influences on land assignment to crops in the Pampas (from Bert et al., 2006)***

Landman (in press) shows how a multi-model forecast system could produce higher skill than single models, and in that study the skill levels associated with El Niño seasons (14 in total) are higher than that of La Niña seasons (12 in total). By contrast, the skill during neutral ENSO phases was not nearly as high; in fact "non-existent" was the finding in that study. It would seem then that a selection process taking place *before* a forecast is issued, attaching the likelihood of decreased (or increased) skill depending on ENSO (and/or other signals), would be justified.

During the collection of data from maize farmers in the MGR, it was also apparent that decisions made by farmers were seldom made under purely rational conditions. The actual weather forecast scenarios were regarded in the light of their own gut-feelings, their experience and the historical record. In many cases decisions were made, but then later replaced or overturned due to new market, weather or political information. It was possible, however, to determine from among the subjects which decisions could be made with the currently available information and which could not.

Certain post-forecast or post-rainfall decisions such as fertiliser application were likely to benefit by the provision of follow-on (especially shorter term) forecasts (Sivakumar, 2006) and by enhancing the more precise and efficient use of fertiliser, reduce excessive GHG emissions and pollution of water resources.

Responses to the question - "Did you change your actions as a result of the forecasts in any of these activities?" – revealed which decisions could be influenced by the forecast.

Decision	Yes Responses n=15
Crop choice	10
Cultivar choice	6
Planting date	6
Other (Marketing)	1

Table 6.3. *Number of farmers who changed specific actions as a result of the forecast*

As a foil to the question above, it was then put to the farmers to recount which decisions were made after rain had fallen, by asking if the actual rainfall had caused them to change their actions. The results (in Table 6.4) show that some decisions, where farmers do not alter their actions, may be pre-meditated, and it could be inferred that the forecast has more influence than they realise. Perhaps the forecast forms the first part of the activity referred to as *satisficing,* as referred to in chapter three. This will be discussed further below.

Decision	Yes Responses n=15
Crop choice	4
Cultivar choice	5
Planting date	11
Other (Marketing)	0

Table 6.4. *Number of farmers who changed specific actions as a result of the rainfall received*

Rubas et al. (2006) describe 4 methods used to model the decision-making processes concluding that education around climate forecasts had the potential of positive payoffs to society in general.

Lemos et al., (2002) suggest that forecasts must not be viewed as *tools* to manage agriculture, rather as *one* available resource, and that farmers should retain the responsibility for decision-making. This raises the question of the importance and value of a forecast in the mind of the user. In the surveys completed, two significant observations were made; firstly that the awareness of forecasts was not as widespread as previously thought, and secondly that the usefulness of forecasts, when accessed, was perceived to be nominal at best. A forecast tool can only be useful if it is accessible (Roncoli, 2006). As both of the available seasonal forecasts in South Africa are available in electronic format only, either publicly on a website or by request as an e-mail, accessibility is constrained by the availability of computer and internet facilities. Some attempts have been made to reproduce the maps into hard copies for extension officer use, but it has been admitted that the officers tend to oversimplify or misinterpret the information themselves.

Farmers did reveal that other sources of information were utilised to support their decision-making, though none were judged to be reliable enough to be indispensible.

Hansen (2002) drew a distinction between *desired* vs *useful* information that forecasts could present. The way in which farmers viewed the information would influence their decisions and have implications on the crop yield. While the farmers in this study were divided equally over how much information they would like to receive compared to what was available (much more, more or enough), none wanted less information and 80% believed that more available information would lead to better decision-making on their part. That the forecast was of some help but required substantial improvement and supplementation was unanimous. The types of additional information requested varied, and are listed below.

- An overview of the whole season, instead of discrete 3-monthly forecasts
- Greater regional differentiation
- Individual monthly forecasts, even fortnightly, if possible
- Clearer explanation and interpretation
- Greater assistance with farm-related decisions
- Early warnings of heat-waves and cold snaps

Ingram et al. (2002), from work in Burkina Faso, showed that farmers were, as seen in this study, more interested in receiving start and end dates of rainfall as well as mid-season interruptions in rainfall, concluding that seasonal forecasts should include an explanation of probabilities, potential response strategies to the forecast including risk management guidelines. They admitted that despite the best forecast information, there might be physical constraints to taking action such as the availability of suitable options. These factors were less apparent amongst the commercial farmers of the MGR in South Africa, but certainly pertinent to the increasing number of emerging farmers in the region. Forecaster modellers are prioritising research into rainfall season start and end dates, but admit that the variation in these dates may be as much a factor or indicator of climate change as detectable seasonal signals (Tadross, pers. comm.).

6.5 Satisficing and cognitive climate dissonance

Farming decisions are made using a finite amount of information, whether financial, historical or personal, and, to a degree, are influenced by the circumstances leading to the issuance, dissemination and interpretation of the seasonal climate forecast. Earlier this was referred to as *bounded rationality* (Simon 1956, March 1988). Within this rational space decisions are made based on the information available. ‘Sensible’ decision making procedures are developed, given the constraining information, and actions follow despite the possible availability of alternative and extra information. This is *satisficing* (Simon 1956, Patt and Gwata 2002). Some forecast users, finding themselves overwhelmed by the array of choice and decision options, settle for the forecast easiest to access, rather than the most suitable (Pagano et al., 1999; Schwarz, 2004))

When a decision is subsequently, in hindsight, recognised as having been incorrect, it is common for cognitive dissonance to occur. This takes the form of regret, blame or anger and is typically reduced through dissonance reduction. Three possible reasons for a cognitive climatic dissonance may be identified; firstly the information was *incorrect*, (as determined by the actual events in hindsight), or it could have been *misinterpreted* or *misunderstood*, or thirdly, an *incorrect application* of the information to the specific situation was performed (this would include rejection of the forecast).

Whereas the blame for the dissonance experienced in the latter two instances can be placed at the door of the decision-maker, the provision of an incorrect forecast could, in the eyes of the users, be seen as the fault of the scientists, who, through misinterpretation, faulty data or even modelling techniques, or deliberate use of forecasts with low skill, have issued an inaccurate forecast. As seen in chapter 2, most forecasts are issued with caveats of some sort and it should be asked whether these assist decision-making among users or not.

Concerning incorrect decisions, farmers were first asked whether their decisions were made independently, or after consultation with others (see Table 6.5). If made independently, it could be expected that dissonance would be more intense. Being able to blame those who contributed to the decision, would allay the regret and allowed the blame to be transferred.

Involvement of others in decision-making	Responses n=17
Solely by themselves	8
In consultation with professionals in the farming industry,	4
In consultation with family or colleagues	5

Table 6.5. *Number of farmers who involved others in final decision-making*

When asked if they had made decisions in the previous season that, in hindsight, they felt were wrong, only 13% said "no". Amongst the 'wrong' decisions, the most common was the fixing of contract prices (6 responses or 38%), a factor of timing rather than a crop related reason. Other decisions, listed in decreasing frequency (n=17), were:

- Poor crop selection (4)
- Planting too early (4)
- Incorrect fertiliser application (2)
- Planting too late (1)
- Wrong cultivar (1)
- Elected not to take out crop insurance (1)
- Spent too much money on spraying pesticide (1)

These 'wrong' decisions go straight to the usefulness of forecasts; if they are to be useful, they should surely address some of these decisions, not necessarily explicitly, but at least after professional interpretation. A clue to the laying of blame by farmers is revealed by the description of their reactions. These were:

- Angry at myself
- Angry and helpless
- Accepted it as part of farming
- Unhappy and upset
- Feeling of regret
- Deeply concerned
- Angry and upset with the inaccurate forecast
- Emotionally drained
- Anger directed towards the farming system
- Resolved to change the approach the following season
- Realistic towards farming risk
- Negative towards farming as a career
- Resolved to be more scientific in management

Most of these reactions are consistent with feelings of cognitive dissonance, and though understandable, reflect a helplessness that may have been avoided through the provision of a more practically applicable and reliable seasonal forecast. That only one comment was specifically directed against the inaccurate forecast is misleading as decisions such as crop and cultivar selection, planting dates, amount of plantings and fertiliser and pesticide application are all decisions that, given a reliable and comprehensible forecast, should be enhanced thereby. It is of course important to acknowledge that a range of external factors may have exerted their influence on these reactions.

When asked if they apportioned blame to those who provided supporting information to their decision(s), the following emerged (Table 6.6):

Where blame was laid	N=16	%
Only blamed themselves	12	74 %
Blamed professional advice they had received,	3	19%
Blaming colleagues or friends	1	7%

Table 6.6. *Where farmers apportioned blame for incorrect decisions*

None was specifically prepared to blame seasonal forecasters for a poor forecast, and when pressed for a reason, all stated that forecasters, and forecast science was, in their experience, fallible.

It seems that the dissonance may be linked to the following two simultaneous cognitions: The fact that the forecasts are essentially accurate because they are probabilistic (cognition #1), and the fact that they do not always provide an accurate prediction of observed local rainfall conditions (cognition #2). The paradox of both cognitions being correct may be difficult for farmers to resolve in any given year, and it may explain the responses that are presented in Table 6.6 regarding where the blame was laid. Farmers in this study seem to blame themselves, rather than the forecast producers, for actions taken when anticipated rainfall conditions do not occur. Placing themselves as responsible may exonerate the forecast's lack of skill at the local level, reducing the dissonance.

Asked whether they had made the same wrong decision before, 45% (7 of 15) answered in the affirmative, with the decisions all involving planting dates or marketing decisions. 95% knew of other farmers who had made similar wrong decisions and 88% said that they had shared their own wrong decision experiences with other farmers. In dissonance theory this is indicative of dissonance reduction and although there was little evidence of consonant cognition, 12% of respondents stated specifically that they had learned from the experience and would be less likely to make the same wrong decision in the future.

Overall, there was little evidence to support a cognitive climate dissonance as such, and yet many of the regretted decisions were made as a result of the rainfall conditions not being anticipated. It was not clear whether this was specifically the fault of the less accurate forecast, a misinterpretation of the forecast skill and/or probability or simply poor, or unlucky decision making.

Lemos et al. (2002), drawing lessons the use of seasonal climate forecasting in policymaking in NE Brazil (FUNCEME), found that the exaggeration of forecast usefulness can create a *cultural* dissonance between science and society. Again they stress that a forecast must not be viewed as a tool to manage agriculture and that farmers must retain decision-making. This study confirms that farmers in the study area were more likely to view a forecast as just one of the available aids to decision-making.

Considering that many farmers felt regret and blamed themselves, and considering that the maize producing region is typically fairly politically and morally conservative, it was posed to them whether they felt that, in such an instance where they felt they had suffered as a result of a wrong decision, that they were being punished by a Higher Power, the response was, with a single exception, an unequivocal “no”.

6.6 Hedging, insurance and other alternative strategies

Farmers have been offered insurance against crop failure and damage due to storms and hail, but this insurance has, according to the respondents, become too expensive. None of the interviewed farmers insured their crops, but some were able to hedge their crops by using varying financial possibilities. Some regarded the financial instruments, such as options, as a form of gambling and were morally against it, but the timing of fixing contracts was regarded by all of them as crucial to obtain the best price for their produce.

Contracts are entered into by a private farmer with a participating trader. The trader, who stores the grain and supplies it to the market, will fix a price for certain fixed future delivery dates and the contract will stipulate an amount. If the farmer cannot supply the mill with the required amount, it would need to be purchased by him at the open market price. As the market price varies during the season, affected by the weather, the supply and the projected total yield, the farmer will often enter into a contract to fix a price that will at least guarantee a profit. The skill (or luck) lies in timing the contract. If the market price is increasing due to external factors, then the farmer will delay his contract, sometimes waiting until he thinks the price has peaked, or when he is confident that his crop is assured. The danger then is that the market price may fall (often due to a projected surplus yield) and subsequent contract prices may fall to values that are below the input cost, thus leaving the farmer with a loss.

All farmers preferred to enter into contracts but each had his own idea of the timing. Generally most would wait until they had a fair to good idea of how their, and the national, crop was likely to turn out given the predicted seasonal climate and the state of their own lands in terms of residual soil moisture. One farmer said he would always wait until February before fixing a contract price, but an interview with a trader produced evidence of contracts being made throughout the growing season. It must be stated that, although farmers tended to regard themselves at the mercy of the trader who was offering contracts at the going rate, the traders themselves were equally exposed to market risk. Figure 6.8 shows how the market price varied over a 26 month period. The input price band (the estimated cost of production of 1 ton of maize) gives an indication of the importance of timing as a marketing decision.

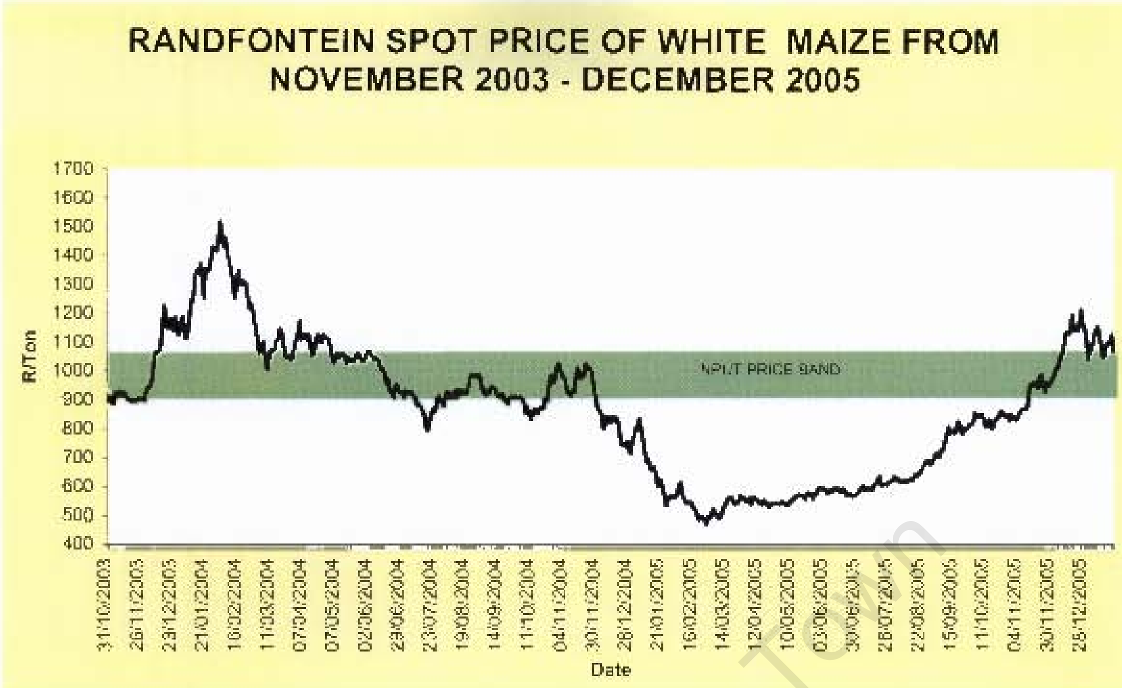


*Figure 6.8. **The price trend of white maize at the Randfontein market between November 2003 and December 2005 The Input Price Band is the averaged cost of farming inputs such as labour, fertiliser and fuel over the period.***

Some farmers participated in the maize futures market by purchasing options. In order to hedge his situation, a farmer would buy an option to buy (a *call*) or sell (a *put*) a certain quantity of maize at a fixed price at a specific future date. The price of the option and the price of the sale are both taken into consideration, before the option is purchased. Kaufmann (1986) described hedging as "establishing a position in a futures contract approximately equal, but opposite to an already existing or anticipated cash position to protect profit margins against an adverse change in price". The main purpose is thus to maintain a position on the price of a commodity in order to reduce risk exposure.

The South African Futures Exchange (SAFEX) controls the trading of these futures and in reality the deals are made in 'virtual' maize. A farmer who has purchased a put (option to sell a quantity of maize) would call in that put if the market price was lower than his contract price – he would not have to deliver the maize but would receive in cash the difference between the total cost of his optional purchase (including the price of buying the put option) and the market price of the maize. In this way he could make a sizeable profit, without ever planting any maize.

In the same way, if he had bought a call (an option to buy maize at a future price) and at that time the market price was higher than his call, he would receive a profit based on the difference in price between what he would have paid for the maize (his call price) and the price he would have sold it for (the market price).

The production of maize underpins the process as all deals have to ultimately rely on actual maize being delivered. The SAFEX would ensure that the trades are all within the bounds of the total supply and demand.

This form of trading, though popular with some farmers, carries a serious risk. The farmer who has bought options may be faced with a worthless instrument if there is no profit to be made i.e. if the optional purchase or sale would lead to a loss. The farmer then does not call in the option, but allows it to lapse, losing only the cost of taking out the option. This, therefore, would be regarded as a type of insurance. The risk is reduced to the cost of the option. However, if the farmer then has reduced or increased his own (actual) production on the basis of his options purchases, without securing a contract with a trader, he stands a further risk of not being able to deliver his crop at a profit, either because the market price has fallen or because his total yield is insufficient.

Most commonly a farmer would buy an option for an amount of maize smaller than his own planned crop, so that if his own crop failed, there would at least be a chance that a profit could be made using the virtual maize of the futures market. In this way, farmers could become less dependent on the weather and other direct on-farm risk factors. They would still, however, be exposed to market risk.

The respondents were polled prior to the 2004/5 season to find out how many elected these alternatives and whether they had been successful. In other research by the author, it was discovered that non-maize farmers and non-farmers were also participating in maize futures trading as an income generating source.

Only six of the seventeen original respondents replied to this poll. Of those, two said that they would not consider the option of futures trading, while one said he was still considering it. Those who did participate had all made profits the previous year and ascribed their success thus:

Reason	Number.
Luck:	0
Skill:	1
Knowledge:	2
Emotion:	0

Table 6.7. *Attribution of success in the futures market by participating farmers*

One farmer, who had made large profits the previous year and had purchased options to buy (puts) admitted in subsequent follow-up that large losses had been occurred. None of the other famers responded.

Why did so few farmers participate in the futures market? One answer was that "I am a maize farmer, not a financial analyst" – this indicated and was backed up by an interview with a Grain SA economist, that farmers were not receiving education regarding futures trading and that in fact it was only the newer generation of farmers that were participating (Lemmer, pers. comm.).

An analysis of the motivation behind those who hedged in this way gives some inkling of how farmers thought they could thereby manage their risk better. The table below shows how each farmer, having been exposed to the seasonal forecast viewed the coming season in terms of yield, price and profit. It also indicates whether they used maize futures and in which format. The maize price at the end of the season is inserted and resultant profit or loss noted.

Immediately it can be seen that, although all farmers expected a lower crop yield due to the drier conditions, none planted alternative crops. It is also interesting to see how their price estimates vary. Considering that they were predicting lower yields, the price would be expected to reflect a lower total crop, possibly a shortage, which would drive the price up.

As it happened, the rains that fell in the January/February/March period were sufficient to produce a surplus crop overall and the price, which had been R1070 at the time of the responses and increased to R1600 in early February before the rains fell, receded to R1140 in May when the harvest took place. A farmer who had thus waited until February before fixing a contract for delivery at harvest in May could have achieved a price of R1600 per ton.

	Farmer					
	1	2	3	4	5	6
Amount of maize planted in 2004/5	Same	Same	Much less	Same	Same	Same
Alternative crops planted?	No	No	No	No	No	No
Expected yield (based on forecast)	Less	Normal	Less	Less	Less	Less
Expected price (p/ton)	1000-1100	<900	>1200	900-1000	900-1000	<900
Expected profit from actual maize planted	Less	Less	Less	Less	Less	Less
Futures bought?	Calls R900	No	Puts R1250	Puts R1080	Considering Puts @ R980	No
Market price May 2005	**1140**					
Calculated result	**Profit**		**Profit**	**Profit**	**Loss**	

Table 6.8. *Season expectations of farmers for 2004/5*

Under such variable market conditions, it is more difficult to assign a direct cause for the cognitive dissonance experienced after a farmer realises that an incorrect marketing decision has been made on the basis of his estimation of the conditions leading to the eventual market price. Would the risk have been reduced if more attention had been paid to the seasonal forecast? One farmer raised the point that an accurate forecast, while benefiting in terms of crop and yield production, may have a counter productive effect of influencing the market prices to the extent where best planning in the world could still lead to reduced profits or losses. This is analogous to a racehorse with proven form, that consequently commands low betting odds. If a forecast has high skill and predicts a good crop, the net result would be surpluses

– this realisation could give rise to a lowering of the price earlier in the growth stages.

Input prices are not fixed due to the variation in quantity and price of fertiliser, fuel and even labour required, but, according to Grain SA and farmers themselves, would typically vary between R800-R1000 per ton. As farmers generally make use of bank loans to provide capital for the coming season's input costs, the return on their investment needs to be substantially above those costs. In 2005, the Standard Bank Agri-review was to say "it is impossible to produce maize at current prices" (http://www.stanbic.com/vgn/images/portal/cit_4931/27/39/14968741Agri_Eng2nd Quarter2005.pdf).

Chapman et al., (2000) investigated whether seasonal forecasts could predict movements in grain prices and concluded that the skill was limited to years where the SOI index was near zero or negative during April/May. A more pertinent question may be whether and how forecasts may influence the grain price and this will be raised in the chapter 7.

A review of the decision-making processes facing a maize farmer before, during and even after a growing season reveals a series of complicated choices involving more than a climate forecast. It shows that a number of factors have greater or lesser importance in the process. In summary the following statements could describe them.

- Seasonal forecasts certainly play a role in assisting the farmer to decide what the general rainfall trend, in terms of expert opinion, may be.

- This information supplements the knowledge, judgement and personal history in forming an opinion of how to prepare, what, and how much to plant, when to fix a contract price, and for how much maize, whether to hedge and in selecting an appropriate instrument.
- Cognitive dissonance, if experienced, would be the result of a wrong decision made on the basis of the above factors, and not specifically directed at a climate forecast or an interpretation of such forecast.
- Risk reduction in an integral part of the farmer's planning and although crop selection was not listed as an important consideration, the date and quantity of planting as well as cultivar selection were.
- Financial decisions such as contracting, hedging and dealing in virtual maize are crucial parts of the planning and execution of the farming endeavour and the timing of such decisions could prove critical in terms of making a profit or loss.

Chapter 7: Conclusion

The trouble with (weather) forecasting is that it's right too often for us to ignore it and wrong too often for us to rely on it.

Patrick Young

7.1 Introduction

The aim of this thesis was to determine, assess and critically analyse the uptake, use and application of seasonal forecasts amongst commercial maize farmers, and to determine the role that climate forecast information plays in their management decision-making processes. As part of the research two key assertions were to be tested.

They were:

- **That seasonal forecasts in South Africa are *not* generally used amongst maize farmers and that even if they receive them, it is unlikely that they will be beneficial.**
- **That seasonal forecasts are only likely to be beneficial when they are more accurate, more focused, more specific and better disseminated than they are currently**

The thesis focused on 3 distinct aspects; the format, dissemination and uptake of forecasts; the validity or usefulness of the forecast; and the dynamics of the decision-making framework of the user with respect to the forecast. Two separate groups of maize farmers were surveyed with questionnaires; one random group which proved to have had little or no exposure to seasonal forecasts and a second selected group who had been exposed to a form of seasonal forecast information. The latter group were sent seasonal forecast products for an extended period of over 4 years. During this time they were interviewed in person and then surveyed after another year. The survey and interview questions were designed to ascertain their views about, and response to, the forecasts, as well as their decision making mechanisms in terms of their farming and risk management. The bulk of the research lay in the interaction with this study group (chapter 4). The responses from the farmers provided a wealth of insight into the use and applicability of seasonal climate forecasts and led to the development of an alternative verification technique.

In chapters 5 and 6 these responses were presented, analysed and discussed in detail. They were then used to form the conclusions, observations and recommendations for this study. It remains to synthesise the key findings and conclusions in order to outline the possible implications for seasonal forecasts in the future and to identify shortcomings and future research suggestions.

7.2 Key findings and conclusions

From the analysis of the results of the surveys and interviews the following findings and conclusions could be determined:

1. The dissemination of seasonal climate forecasts among maize farmers was generally poor due to:
    - Limited access to the forecast

- Lack of exposure to the forecast and what it meant
- Scepticism among farmers towards it

2. The uptake and usefulness of seasonal climate forecasts amongst maize farmers depend on 3 major factors:
   - The trustworthiness of the forecast – the lack of perfect skill was not of major concern, with farmers acknowledging that it could not be right all the time. They wanted a product that they could rely on to be *mostly* accurate, which in their context meant at least 3 times out of 5
   - The nature of the presentation so that the information and its implications could be understood and applied
   - Added value in terms of interpretation of the forecast content for their specific purposes

3. The usefulness of the forecast is constrained by the following:
   - Many on-farm decisions can only be made once rain has fallen
   - Farmers do not understand probability well enough to make informed decisions from it
   - Spatial resolution is too low for farm use
   - Access is limited to electronic media, which is slow and cumbersome in parts of the country
   - Additionally it was apparent, though not categorically shown through the surveys, that, if the forecast is regarded as skilful, and is widely accepted and acted upon, it could affect the market prices at an earlier

time in the growth phase. This could reduce the volatility of the prices and impact on the nature of the gamble that contracting is presently.

4. A simple alternative verification scheme showed that during the previous 5 growing seasons in the maize growing region, on average the forecast showed a skill value of +6.9 (on a range of -10 to +10) offering farmers a way of assessing the usefulness in the region for particular periods. It was also able to convert probable rainfall percentages into ranges of expected rainfall during the periods of higher skill, something that farmers deemed a desirable improvement on existing forecasts. The verification scheme should serve as a limited, but valuable example of the assessed usefulness of the forecast over the 5 year period.

5. The potential for increased utilisation in the future includes greater application in specific decision making such as:
    - Planting dates planning to avoid the mid-season drought occurring at a water sensitive time for the plant.
    - Timing marketing of the crop, specifically the fixing of contracts and hedging opportunities to leverage the best prices.

6. The psychological aspect of forecast belief, trust and acceptance revealed that farmers mostly regarded the decision to use or not use a seasonal forecast as an acceptable risk, and in the case of poor decision-making, they did not blame the forecast, but rather themselves or their circumstances. Cognitive *climate* dissonance did not seem to be justified as a concept.

In assessing whether the main assertions made were valid the above were considered and incorporated into the following comments.

The **first assertion** (that seasonal forecasts in South Africa are *not* generally used amongst farmers and that even if they receive them, it is unlikely that they will be beneficial) was given **provisional validity** in that among the farmers surveyed in a random sample, very few had heard of, or experienced, a seasonal forecast for themselves. Despite that, it is known that the South African Weather Service (in the past) and Maize Vision have sent out forecasts by e-mail to hundreds of subscribers. This does not seem to be the case at SAWS at present (Landman, pers. comm.). The lack of mass uptake together with clear evidence of (largely un-communicated) skill demonstrates that there is much more potential for reaching not only commercial farmers, but also smaller and emerging farmers, as well as other less obvious sectors.

The use of seasonal forecasts cannot yet be said to be generally beneficial amongst farmers. In this research many said they considered the forecast but did not make many specific decisions based on it. Whereas the economic implications of the forecast were not explicitly investigated here, it was apparent that the profit margins experienced were not *forecast* related, but actual *weather* related. It remains to be seen how farmers can be persuaded to put more faith in the forecasts and then to determine the monetary benefits (if any). The usefulness of the forecast in terms of timing of contracts and hedging strategy may be more significant than was apparent here and more research is required.

The **second assertion** was that seasonal forecasts are only likely to be beneficial when they are more accurate, more focused, more specific and better disseminated than they are currently. This assertion receives **unqualified validation** as most of the findings testify to the fact that farmers *want* forecasts and they believe that they could and would be more useful if they were more skilful, more directed and more interpretative. On-farm responses to the forecasts as recorded in this research show that there is great potential for social benefits form an improved forecast. It remains to be seen how realistic it is to expect this improvement and yet, in many cases, improvement in skill is not absolutely essential. By communicating the current skill, shortcomings and resolution constraints of the forecast, already a great stride is made to allow farmers to place more validity and trust in the products.

One concern is that the seasonal forecast development may have reached a point where further skill development occurs at slower rate, due mainly to a decline in research as a result of the focus on climate change. In this scenario, it may seem that further research without improvement in skill would not be justified in terms of expense and time. However, if this happens then the dependence of existing forecasts will be affected in one of two ways. Either, users will recognise the shortcomings of the product, but having realised that some usefulness existed, would encourage the development of tailored products to suit their unique situations, or, having been sceptical from the start, and in the absence of any further value-adding, would tend to continue to make decisions without taking the forecast into account. There is no doubt that forecasts will be very skilful occasionally and that benefit would accrue from taking this into account, but whether, over the long term, this skill is translated into accuracy is unknown.

On the other hand, the development of, and demand for, climate change forecast models should provide a platform for developing shorter term seasonal forecasting models as well. This would augur well for the future of seasonal forecasting. One potential improvement would be the integration of future hazards or extremes which would be able to assist in the seasonal forecasting context of disaster risk management.

It is notable, however, that Stainforth et al. (2007) suggest that climate prediction (and by inference, seasonal climate prediction) may already have approached the limits of deterministic capability with the remaining variance a function of atmospheric chaos principles. Instead of being able to predict a single future scenario, it would be more realistic and *ergo*, more accurate, to characterise an envelope of possibilities. This will require more research into the confidence and requirements of predictive climate science.

7.3 Implications and prospects for seasonal forecasts to maize farmers

Seasonal climate forecasts have been widely assessed elsewhere in terms of serving the interests of users better and these findings and conclusions will support many of these assessments. The production of new forecasts will always seek to utilise detectable signals whether in sea-surface temperature fluctuations, oscillations or reversals, and the scientists who build, guide and fine-tune the models should be supported in their efforts. It remains of paramount importance to maintain and improve the relationships between these scientists and those who aim to apply the forecast output to general or specific user requirements. To this end, constant dialogue and information exchange must be encouraged and supported. While user fora serve to engage, inform and educate those who seek to apply the forecast information to their needs, intermediaries are always required to bridge the gap between the users and the scientists in order to facilitate recognition and understanding of the challenges, constraints and potential of future engagement and cooperation.

These intermediaries, or *forecast advisors*, need to serve two specific and possibly separate, roles. Firstly, they need to interpret what the scientists can provide through the model output (and what they can't). The information needs to be *understood* in terms of how it was derived, the sources of uncertainly in the various stages of data collection and assimilation, and the intentions and purposes it was designed to serve. Secondly the information needs to be *assessed* for its usefulness to specific users and then, thirdly, it must be *aligned* to their needs. Farmers often expressed the need for the information to be tailored to their specific application – this would include their crop choice, their climatic regime, their soil and the resources they would be able to access in order to act on the forecast information. The latter role is especially suited to agricultural specialists and although extension officers are trained and used to assist farmers, the skills required are more suited to professionals. This by no means reduces the responsibility and value of extension officers. They too should be involved in this task, working closely with specialists and being able to convey the appropriate information accurately to their constituents (Msangi et al., 2006).

An immediate caveat that arises is one which is easy to overlook, but has been raised by scientists and researchers; the value of forecast information must not be exaggerated (Henderson-Sellers, 1998; Patt and Schrag, 2003). The temptation to exaggerate the skill, usefulness and potential gains of a forecast has resulted, and can still result, in over confident and bold decision-making with grave financial and credibility consequences. The well documented ENSO forecasts of the 80's and 90's that varied from highly successful to very poor are prime examples.

One constant concern among farmers is the duration and timing of the rainy season. The onset of rain can vary by months, in some cases, and the length of the available growing season is a critical factor for a successful crop. Since the onset may be premature, in that initial rains may not be followed up with required moisture to sustain plantings, farmers have tended to be reactive in this sense. Only when they were reasonably confident that the available soil moisture would be able to sustain a dry spell, would farmers undertake planting. The threat of a mid-season dry spell occurring during a high risk period for the crop is also a serious concern. For these reasons it seems sensible and opportune for forecasts to offer scenarios that take these risk factors into account. The forecast information package should take antecedent conditions into account, relating the existing soil moisture to the prospects of rain to create a planting index of sorts. Once the index is favourable and planting is completed, monthly and 3-monthly forecasts need to be seamlessly integrated into the short term forecasts (see Doblas-Reyes et al., 2006), so that the farmer can combine the macro information with the local short term weather prospects. This offers him a way of reacting to the weather, with an overall understanding of the seasonal scenario within which to contextualise it. Throughout the process of the forecast integration and application, the verified skill of the forecast should be stated for the temporal and spatial scale to which it can be applied.

An example of how this could be accomplished would be for forecast advisors to consider the seasonal forecast in terms of existing soil moisture, to identify planting windows in terms of short term rainfall forecasts and then to time integrated forecast compilations to coincide with the critical risk periods in the phenological stages of the crop's development. This would allow farmers to better identify the high risk periods of their crop and the forecast. If a forecast had low skill for a particular region or period then the farmer would be availed of that information, so that cognitive dissonance, in the case of regret, is limited to the farmer himself and not directed at the forecaster or forecast advisor.

The usefulness of a forecast will always be predicated on the tension between *necessity* and *skill*. When the farmer most needs a forecast and the skill is low, his exposure to risk will rise, although the possibility of higher reward is also present. The relationship between forecasts and market prices is still unclear. An example from the 2002/3 season in Figure 7.1 below shows the price curve for June maize contracts during the season. The monthly seasonal forecast from SAWS is superimposed, and the mean and observed rainfall figures from Kroonstad, near the centre of the MGR are also shown.

By inspection of the forecast information, the rainfall and the price trend, and considering the options available to farmers, the following deductions can be made:

- The forecasts issued during the early part of the season indicated a tendency towards a dry season. The apparent impact on the price, which was already high following a regional maize shortage in 2001/2, was negligible. This may be explained by the fact that the price was approaching import parity.
- The low rainfall in October and November compounded the prospects for yet another maize shortage but, although the forecast had proved skilful, the price increased only after rainfall figures were released.
- The December rainfall, which exceeded the long term mean by 50%, and which could not be inferred from the probability forecast, would have had an immediate effect on crop conditions and the price began to fall, continuing well into February, despite the follow-up rains remaining below normal.

  The price remained low for the rest of the harvest due to the crop recovery (see below). The crop recovery was due to the timing of the above-average rainfall during December, and occurred despite the low overall seasonal rainfall (forecast *and* observed).

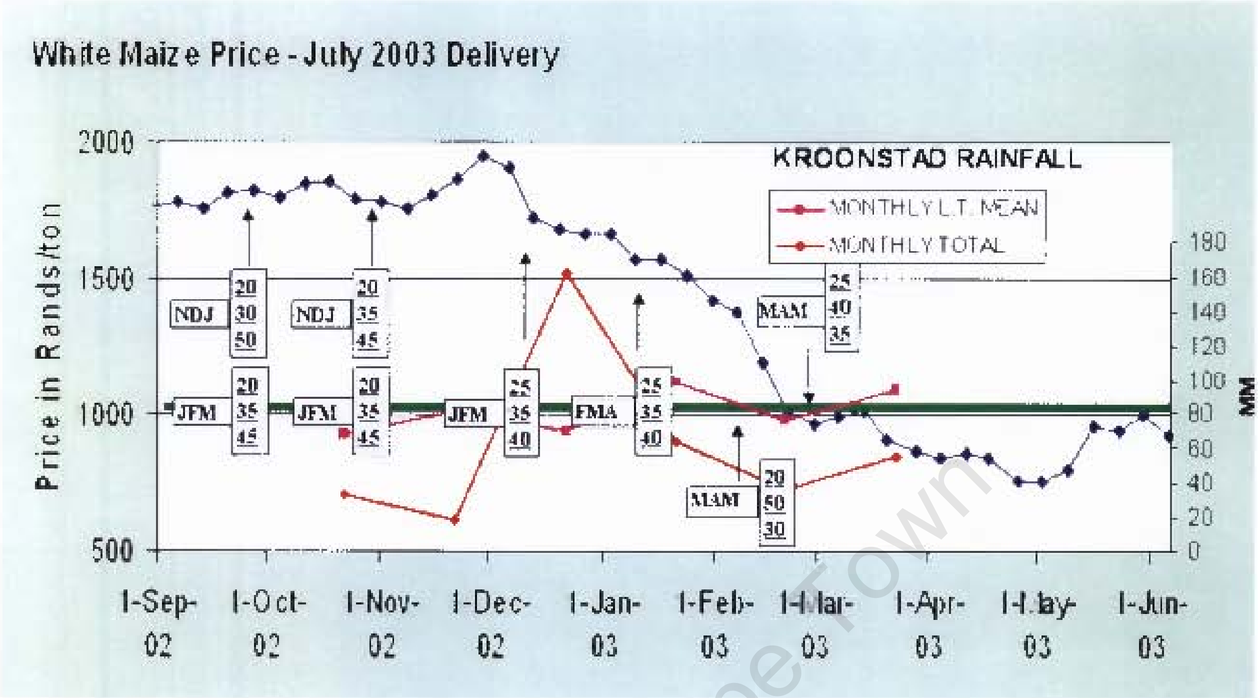


Figure 7.1. ***The price curve for June maize contracts during 2002/3. The monthly seasonal forecast from SAWS is superimposed, and the mean and observed rainfall figures from Kroonstad are also shown.***

Due to favourable conditions in February (see Figure 6.6), the final 2002/3 total South African maize harvest was 5.576 million tons at an average yield of 2.8 T/ha. The market price reflected the impact of a surplus of 1.718 MT remaining low until peaking again at over R1000 per ton in November 2004. The situation a year later was reviewed in January 2005, after a similarly late start to the rainy season.

> *Current maize prices of about R600/ton for white maize on Safex are the lowest in four years. Maize prices have dropped by more than 50% in the past year and were at R1024/ton as recently as November 2004. The present low prices are the result of a number of factors, including large carry-over stocks from the 2004 crop, relatively low international prices, the rand's strength against the dollar* ***and the***

> ***better than expected*** *rainfall, which has boosted the prospect of a maize crop in excess of 9 million tons.(The South African) ..market can realistically absorb about 8 million tons.*
> *Government subsidies in other countries make it difficult to export surplus maize and since deregulation of the local marketing system, maize exports have virtually disappeared from the world market.*
>
> *Department of Agriculture:* ***Assessment of Current Economic and Physical Environment of Agriculture January 2005***
> http://www.nda.agric.za/docs /ass_eco_phy_SA.pdf

This dramatically reveals the inherent volatility of the South African maize market. If even a moderately good harvest is achieved, the build-up of surpluses from previous years may force the price down. The department of agriculture has in recent years encouraged fewer plantings depending on the surplus levels, regardless of the climate forecast.

It is evident from these two examples that seasonal forecasting information would, at best, assist a farmer to plan for the expected crop growing conditions, provide crop yield estimates and give him an inkling of what the market may do, but that the most beneficial outcome for his farming operation is a delicate combination of market factors and weather conditions.

The Standard Bank review in 2005 provides very salient, but possibly biased, advice to farmers regarding financial advice on a season by season basis. In the following excerpt, it suggests that farmers use options instead of contracts, and offers some sensible advice that is seemingly independent of any weather projections.

It is suggested that farmers should mainly use call and put options for hedging rather than future contracts because of their cash intensive nature. Options are the most effective way to hedge against price risk. They give farmers flexibility as they are not "locked" into the market at a set price. If maize prices increase before the expiry date, farmers could simply let their options contracts expire. They would then be free to take advantage of the price increase in the physical market through forward contracting or cash sales. On the other hand, if prices fall below the target, the farmer could exercise his option by selling his maize crop on Safex at the target price less the premium and brokerage fees.

What should maize farmers do?

The implications for the maize farmer are:

- *Know the cost of producing a ton of maize, this will give you clarity on whether to plant maize in the coming planting season or not;*
- *Contract a fixed price through delivery contract before the production season starts at levels above the cost of producing a ton of maize. If the planting season starts without you knowing where your produce will be sold, it is advisable not to plant maize at all;*
- *Hedge the price on Safex at levels above the cost of producing a ton of maize. Farmers who hedged against price declines early this season will have secured relatively good prices for at least two thirds of their maize crop.*

The Standard Bank Agri-review 2nd Quarter 2005.

(http://www.stanbic.com/vgn/images/portal/cit_4931/27/39/14968741Agri_Eng2ndQuarter2005.pdf).

The implications for the future of seasonal forecasts in terms of best serving the commercial farmer now seem to be even more complicated. A forecast would need to be integrated into this market information so that the best all round information can be provided (Doblas-Reyes et al., 2006).

7.4 Limitations of these findings and suggestions for future research

This research project has several limitations that became evident during its duration.

- The response to the initial e–mail survey was poorer than the response garnered at the NAMPO harvest festival and the follow-up surveys were not as enthusiastically supported as one may have hoped. In the author's opinion, the perceived benefits to the farmers were not great enough for them to reveal their innermost feelings regarding their farming decisions.
- The study does not take non-commercial farmers into account, although the assumption is made that on a national food-security level, benefits to commercial farmers would be in the country's interests.
- The developed verification forecast technique has not been scientifically tested nor has it been peer-reviewed. It has however offered a simple way for farmers to grasp the meaning of accuracy and skill in a forecast.
- The impact of seasonal climate forecasts on market trends has not been sufficiently evaluated. Forecasts would need to be fully integrated with market responses to provide the best possible opportunity for the farmer to

benefit financially from the information and to ensure food security for the nation.

The prospects for further research are good. Physical climate models are improving every year, the understanding of atmospheric physics is growing and the academic and public popularity of climate change prediction has drawn more interest into the field of climate science. From the social and humanities side, cross-cutting issues such as environmental awareness, human and ecological vulnerability, and disaster management are all bridging the gap between science and society in order to find solutions.

The following research avenues are recommended within the ambit and scope of seasonal forecasting and agriculture:

- An investigation into verification methodologies to identify and apply simple but effective skill values that can be attached to forecasts for specific areas and time periods.
- Further investigation into the relationship between climate and weather forecasts and market trends, especially as far as futures pricing is concerned.
- Research into the feasibility of farmers becoming more active in options trading and the impact this could have on food security.
- Active analysis of the flow of forecast information within the agricultural sector to ascertain the introduction and persistence of error, misinterpretation and over-confidence.

- Focused links between forecast information and specific on-farm decisions of other of types of farming in order to assist subsistence and emerging farmers
- Investigation into the cascade of error with interpretation and dissemination of forecasts from producers, via intermediaries to users
- In Australia, *Whopper Cropper* (http://www.apsru.gov.au/apsru/Products/Whopper/whatis.htm) enables crop management advisors to predict the crop yields in various regions for the upcoming season, based on starting soil conditions and the current phase of the SOI, as well as historical records. A similar application for Southern Africa would be most welcome

In summary, this research has contributed to the body of knowledge on the subject by raising and highlighting four main issues:

1. Seasonal climate forecasts have not been able to reach and assist the average maize farmer in a way that makes a significant difference to his farming success. That they are doing the best they can with the current state of the science is offset by the fact that users do not understand the limitations of scale and skill sufficiently to apply the broad message the forecasts are giving, that is a guide to departures from normal conditions based on specific ocean/atmosphere signals registered and applied by the models.

2. There are three main reason for this:
    a. The dissemination of forecasts is poor due to the lack of a concerted and directed effort by forecast producers and/or government

b. The format of the forecast is confusing and lacks clear skill indications

c. Other factors such as the variation in financial markets play an important role in the profitability of a farming enterprise

3. Bearing the above in mind, it is difficult for users to build up a credible and positive attitude towards forecast products

4. There is evidence that forecasts have the potential to be interpreted and analysed by forecast advisors to better serve the user community

This work has shed a different perspective on the assumption that forecasts, as they are issued, provide real benefits to farmers. This places a considerable burden on the research community to augment the forecast products so that some measurable social benefit can accrue.

Having stated that, and although some of these issues listed above may infer that seasonal forecasts are not effective, it is towards a positive outlook of the future of seasonal forecasting in South Africa, and the region, that this research hopes to have contributed.

Appendix 1: Survey to maize farmers at NAMPO harvest festival

NAMPO – Farmer Questionnaire – 14/15/16 May 2003

Date: ……………………
No: ……………………..

Location …………………………………………………………

1. Type of farm(private, community, company):
   …………………………………………………………………………………………

2. Farm size: ………………………………… (in ha/acres)

3. Household size: ………………adults ………… Children

4. How many family members do you support/

5. No. of buildings …………………………………………………………………..

6. Any irrigated fields ? (%)………………………………

7. No of livestock & types:

Type/tipe	Number/getal	Purpose/doel

8. Type and number of labour employed on farm

Family ……………..   Managerial: …………

Hired (full time) ………….. Hired(seasonal) ……………..

Other (specify) …………………..

9. Main crops/

Crop	Area (hectares/ acres)	% marketed	Est yield: good/ave/poor

10. Over the last 5 years how often has your farm been profitable?

1	2	3	4	5

11. Sources of income:

Sourc/	Type and details	% income
Agriculture		
Livestock		
Commercial Business		
Gov grant Eg.Pension/		
Other (specify)		

12. Can you borrow money if you need it ? Y…… N:……..
If yes

a. from whom?……………………………………………………….………………

b. under what conditions?…..…………………………

…………………………………………………………………..………………

13. Compare the activities this season with those of the last; and state why you made the change:

Activity	**This season**	**Reason**
Prepare more/less/same amount of land-		
Time of land preparation/ datum van		
Plant crops earlier/later/same)		
Plant different crops to last year		
Change crop cultivar		

Activity/	**This season**	**Reason/**
Fertiliser application		
Irrigation		
Stocking rates/		
Borrowing money		
Other		

14. Did you consult anybody in making these decisions
Y……. N……….

If yes

a. Whom did you consult?……………………………………………………………...

b. Was there someone you could have consulted but did not?
……………………………………..…………………..

15. Did you receive any **seasonal climate and weather** forecast advice available to you that aided in the above decisions -Explain

………………………………………………………………………………………

………………………………………………………………………………………

……………………………………………………………………………………

IF YES, (IF NO, go to Q 20)

When did you receive it?…………………………………………...

16. Please describe the forecast in your own words(probability/ total seasonal amount/time of onset ?)

………………………………………………………………………………………

………………………………………………………………………………………

17. Did you believe the forecast??

1. Yes, explain …………………………………………………………..
2. No, explain ……….……………………………………………

18. Was the information relevant to your needs?

1. Yes, explain ……………………………………………………………
2. No, explain …………………………………………………………

19. ..Would you like to receive a forecast with respect to the probability of /

ABOVE NORMAL
NORMAL and
BELOW NORMAL rains for the season?

Y …….N……..Unsure

If **YES**,

20. What would be your chosen method of receiving it?

1. Meteorological bulletins	
2. Newspaper/	
3. Radio	
4. TV	
5. Ag extension officer/agency	
6. Post	
7. Co-op	
8. Internet	
9. Other ……………………………….	

a. In which month would you like to receive it in?.

b. Which of the following pieces of forecast information would you find the most useful?

(i) total amount of seasonal rain …………….
(ii) time of rain's onset …………….
(iii) Seasonal distribution of rainfall…………
(iv) other……………………………………………………………

21. Are you aware of what crop management your neighbour/s took this season/
....

If Yes, did this influence your decisions and why?
....

....

22. If you had known the way weather would turn out, in hindsight would you have reacted differently/
....

....

23. How reliable would you judge the advice you received from?

	GOOD	**AVERAGE**	**POOR**
Maize Vision			
Media			
Co-op			
Agricultural Extension			
Farmers Unions			
Other/Ander			

24. What additional types of information would you like to receive?

From:

a. Maize Vision ....

b. Media
....

c. Ag Extension/ ....

d. Farmers Unions ....

e. Other ....

25. If the information you received was only reliable 2 out 5 times would you still want to receive it?

Y.....   N....

26. For the forthcoming season, if there was a rainfall probability of

30 % of above normal / Bo-normaal
50 % of normal/ normaal
20% of below normal/ Onder normaal

What would your expectation of the season be? –
GOOD,   AVERAGE   POOR   NOT SURE

23. If the **probability** of rainfall is given as **60%** for today, how would you interpret this?

…………………………………………………………………………………………

24. Are you confident in your understanding of the concept of rainfall ***probability***Y….N…..

25. What are your feelings about the following aspects of **seasonal** forecasts??

a) the lead time (usually 6-1 months beforehand with increasing confidence)

…………………………………………………………………………………………

…………………………………………………………………………………………

b) the temporal resolution - currently months/season

…………………………………………………………………………………………

…………………………………………………………………………………………

c) the spatial resolution - usually between 100-200 km – acceptable or not?

…………………………………………………………………………………………

…………………………………………………………………………………………

26. If the forecast was incorrect one year would you use it the following year? Y…..N….

27. Are there any natural signs that you use to predict the long term rainfall ?

…………………………………………………………………………………………

…………………………………………………………………………………………

28. (if applicable) Specifically regarding Seasonal Climate forecasts – what improvement, changes, or comments would you have

…………………………………………………………………………………………

…………………………………………………………………………………………

29. (if applicable) Specifically regarding Maize Vision – what improvement, changes, or comments do you have

…………………………………………………………………………………………

…………………………………………………………………………………………

THANK YOU

Appendix 2: E-mail survey to targeted maize farmers

E-mail Questionnaire - September 2003

Date: …………………… **No: ……….**

Location of farm (district, town): …………………………………………………

1. Farm size: ………………………………… (in hectares)

2. Main crops:

Crops	Area (hectares/ acres)	% marketed	Est yield (Good, average or poor)

3. Do you irrigate any of your land? **YES** ☐ **NO** ☐ ……….%

4. No of livestock & types:

Type	Number	Area allocated	Purpose e.g. meat

5. How many of the last 10 years has your farm made a profit/broke even/made a loss?

Profitable	Broke even	Made a loss

6. Sources of income:

Source	Type	% income
Crops		
Livestock		
Commercial Business		
Other (specify)		

7. Expenses/costs

Source	Details (if applicable)	% costs
Seed		
Fertiliser		
Feed		
Fuel		
Labour		
Equipment hire		
Other (specify)		

8. What is the average annual rainfall in your district…………………………….mm

9. Compared to the district average, do you think your farm generally receives

   ABOVE □ **BELOW** □ or **THE SAME** □

10. Do you keep rainfall records? If yes, for how many years do you have records?

    YES: □ . **NO:** □ **YEARS**?: ……………………..

11. Do you use climate records to assist your decision-making?
    YES: □ **NO:** □

12. Have you ever previously used a **seasonal rainfall forecast** of any sort? **YES** □ **NO** □.

    IF **YES**…..

    12.1 Who produced it?:
    ……………………..……………………………………………………

    12.2 What lead-time[5] did the forecast offer?

1 month	2 months	3 months	3-6months	More than 6 months

    12.3 Did the forecast give *probabilities* of rainfall? **YES:** □ **NO:** □
    Did the forecast indicate when the first rains (onset) would fall? **YES:** □ **NO:** □

[5] Lead-time: how far in advance of your interest period was the forecast made. For example, if you were considering information for November, then a forecast made in October would be a 1-month lead-time.

12.4 Did you believe the forecast? **YES** ☐ **NO** ☐ Explain:

....

12.5 Was the *information* relevant to your needs?

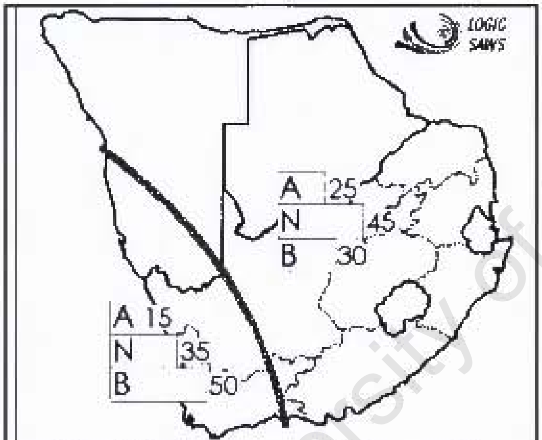
Not at all	Slightly	Fairly	Very much

12.6 To what extent was the seasonal forecast information important in your *planning*?

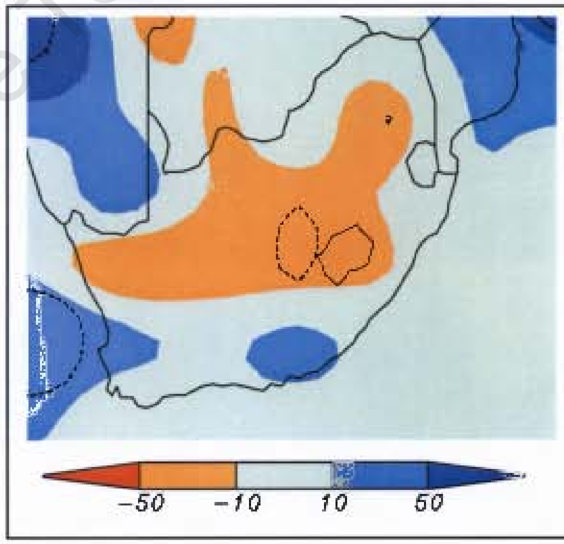
Not at all	Slightly	Fairly	Very much

13. Would you like to receive a seasonal forecast every year? **YES** ☐ **NO** ☐

At present forecasts are generally issued in one of two formats – see the attached forecasts:



Probability of above-normal (A), normal (N) and below-normal (B) conditions.



(A)% Probability for each category of rainfall **(B)% Expected difference from normal**

13.1. Which would you find prefer to receive? **A** ☐ **B** ☐ **Neither** ☐

14. What would be your chosen method of receiving it?

Meteorological bulletins	
Newspaper	
Radio	
TV	
Agr extension officer/agency	
Post	
E-mail	
Internet	
Other/	

15. In order for a **seasonal climate *forecast*** to assist in making the management decisions below, what information characteristics would be required/useful? (Remember that the forecast information would be issued *before* the rainfall season and will not always be 100% correct)

Activity: *Enter 1-4 in each box: 1 – very useful 2 – useful 3 – not useful 4 – don't know*	**Forecast with more than 1 month lead time (greater lead time = less skill)**	**Prediction of monthly rainfall anomaly[6]**	**Prediction of 3-monthly average rainfall anomaly[6] only**	**Historical rainfall probability (based on SOI – El Nino index)**	**Approximate date of onset of rainfall**	**Approximate date of cessation of rainfall**	**Intra-seasonal[7] distribution of rainfall**	**Approximate timing and duration of dry spells**	**Average temperature anomalies**
Amount of Land prepared									
Crop Planting date									
Type of crops planted									
Selection of crop cultivars									
Fertiliser purchase									
Irrigation planning									
Stocking rates									
Borrowing money									
Other									

16. The spatial resolution of seasonal forecasts is typically 250km by 250km this is the finest detail that can be distinguished. Is this acceptable in assisting you with above decisions?

Very useful	**Useful**	**Not useful**	**Don't know**

[6] An anomaly shows the difference between the forecast value and the mean value
[7] Intra-seasonal rainfall refers to forecasts of rainfall for shorter time periods, for example for each month in a 3 month season.

17. In which month(s) would you prefer to receive a forecast?

Before August	August	September	October	After October

18. What minimal accuracy in a seasonal rainfall forecast would you find of value? For each forecast attribute select the frequency of correctness that you would require.

Prediction attribute	No of Times Correctly Predicted 1 in 5	2 in 5	3 in 5	4 in 5	5 in 5
Total Rainfall: Above-, Below- or Near-Normal					
Within 20% of actual rainfall					
Within 50% of actual rainfall					
Onset of rainfall corect to within 1-3 weeks					
Onset of rainfall correct to within 3-6 weeks					

19. If you had known the way the last **season's** rainfall would turn out, in hindsight would you have acted differently in these areas?
    a. Crop selection YES ☐ NO ☐
    b. Cultivar selection YES ☐ NO ☐
    c. Planting date YES ☐ NO ☐
    d. Other ....

20. How reliable would you judge the climate-related advice you received from?

	GOOD	AVERAGE	POOR
Maize Vision			
Media			
Co-op			
Agricultural Extension			
Farmers Unions			
Other			

21. For the forthcoming season, if there was a rainfall probability of : 35 % of **above normal**
45 % of **normal**
20 % of **below normal**
What would your expectation of the rainfall be?

GOOD ☐ **AVERAGE** ☐ **NOT SURE** ☐

22. If the **probability** of rainfall is given as **60%** for today, how would you interpret this?

    a. 60% of the region will receive rain today .... ☐
    b. It will rain 60% of the time today .... ☐

c. 60 times out of 100, under similar conditions as today, it would rain
d. There will be 60% of the average daily rainfall today ....

23. How confident were you in your answer regarding the rainfall ***probability*** above (Q23)?
Very □ **Fairly □** **Not really □** **Not at all □**

24. Have you ever used **crop modelling** output or information (growth/yield forecasts) to estimate/predict your crop yield? **YES □** **NO □**
If **YES**...
   a. Was it helpful? **YES □** **NO □**
   b. Would you make use of it again **YES □** **NO □**

25. Would you find it useful to have access to **historical rainfall and crop data**?

YES □ **NO □** **NOT SURE □**

26. Are there any natural signs that you use to predict the long-term rainfall? If so, describe ......

....

....

27. Do you think you will find the accompanying forecasts useful? **YES □ NO □**

Any comment? ....

....

28. Does the fact that they are not identical bother you? **YES □** **NO □**

29. Which one do you think is more likely to be accurate?

A (SAWS) □ **B (UCT) □** **NEITHER □**

30. What suggestions for improvements and changes, or any other comments do you have for the producers of seasonal forecasts?

....

....

31. Specifically regarding Maize Vision – what improvement, changes, or comments do you have?

....
.

....

THANK YOU!

Name ....Tel: ....

Email: ....

Appendix 3: Follow-up interview with maize farmer study group

Follow up Survey - personal interviews 15-20 Aug 2004

Date: .... **No:** ....

Farm location (district/town): ....

Name .... **e-mail:** ....

Tel: ....

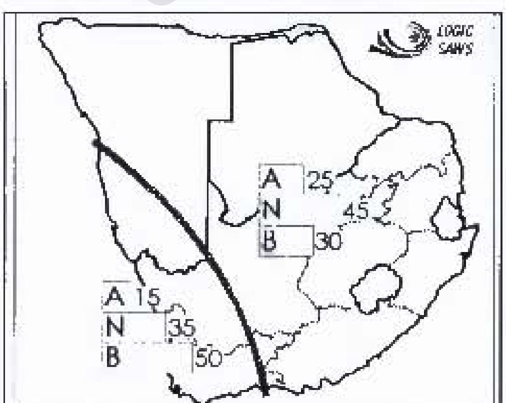
1. Main crops for 2003/4:

Crop	Area (hectare/ acres)	% market-ed	Estimated yield (Good, average or poor)	Actual yield (more, as est., less

2. Did you *break even/make a profit/ make a loss* with your maize crop of the last season ?

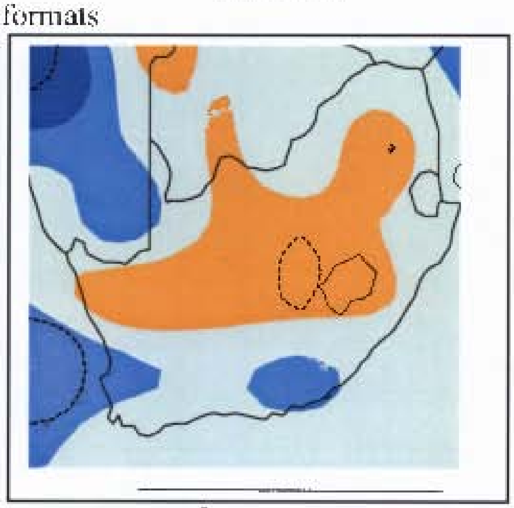
Profit	Broke even	Made a loss

3. In terms of the normal rainfall for your region do you think that last season you had, **more, average**, or **less** rain
   MORE ☐ **LESS** ☐ **AVERAGE** ☐
4. Do you think your farm received the same rainfall as the rest of the district?
   MORE ☐ **LESS** ☐ **SAME** ☐
5. Forecasts were provided to you in two formats



Probability of above-normal (A), normal (N) and below-normal (B) conditions

(A) % probabilities for each rainfall category



(B)% of normal rain expected

5 Which format did you prefer? **A** ☐ **B** ☐ **Neither** ☐

6 Which do you think was more accurate?

A (SAWS) ☐ **B (UCT)** ☐ **NEITHER** ☐

7 Was the fact that they differed a problem? **YES** ☐ **NO** ☐

8 Did you *use* the seasonal forecasts? **YES** ☐ **NO** ☐
IF **YES**
8.1 Which one? **A (SAWS)** ☐ **B (UCT)** ☐ **BOTH** ☐.

8.2 For which forecast period is it the most useful?

1 month	**2 monthes**	**3 monthes**	**3-6monthes**	**More than 6 months**

8.3 Was the forecast's *probability* accurate?
YES ☐ **SOMETIMES** ☐ **NO** ☐

8.4 Did the forecast indicate when the first rains would fall? **YES** ☐ **NO** ☐

8.5 Did you believe the forecast? **YES** ☐ **NO** ☐ Explain:

…………………………………………………………………………………

8.6 Was the information relevant for your purposes?

Not at all	**Slightly**	**Somewhat**	**Definitely**

8.7 To what degree was the forecast information important for your *planning* on the farm.? (Did you make any decisions based on the forecast?)

Not at all	**Slightly**	**Somewhat**	**Definitely**

9. Did you make any different decisions as a result of the forecast as far as the following are concerned?
   a. Crop selection **YES** □ **NO** □
   b. Cultivar selection **YES** □ **NO** □
   c. Planting date **YES** □ **NO** □
   d. Marketing **YES** □ **NO** □

10. Did the actual rainfall change any of decisions wrt?
   a. Crop selection **YES** □ **NO** □
   b. Cultivar selection **YES** □ **NO** □
   c. Planting date **YES** □ **NO** □
   d. Marketing **YES** □ **NO** □

11. Would you like to continue receiving these forecasts? **YES** □ **NO** □

    Why (not)

    ……………………………………………………………………………………..

    ………………………………………………………………………………………

12. List the greatest risks you face in your farming activities.

    ………………………………………………………………………………………..

    ………………………………………………………………………………………

13. Which management decisions depend on these risks (in order of importance).

    a. …………………………………
       i.………………………..…………….
       ii.…………………………………….
       iii.……………………………………

    b. …………………………………
       i.………………………………………
       ii.………………………………………
       iii.………………………………………

    c. …………………………………
       i.………………………………………

ii……………………………………

iii……………………………………

14. Which of these decisions vary from year to year?

……………………… ………………………..

……………………………..

15. Do you make your own decisions or do you take others' viewpoints into consideration?

Own ☐ **Someone else** ☐ ……………………………………

16. Have you made decisions in previous years, which, in hindsight you now know were wrong? Name them.

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

17. What were the consequences of the so-called "wrong" decisions?

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

18. How did you react/respond when you realised that the wrong decision had been made?

……………………………………………………………………………………

……………………………………………………………………………………

19. Did you, in any way, blame the person/s who provided you with information or opinions upon which you based your decision?

YES ☐ **NO** ☐ Whom?

………………………………………………..

20. Have you done/ will you do anything to ensure that you do not make the same "wrong" decision again?

....

....

21. Have you ever made the same "wrong" decision again? **YES** □ **NO** □
    Which?

....

22. Do you know of other people who have made the same "wrong" decision? **YES** □ **NO** □

23. Did you share your experience with them? **YES** □ **NO** □

24. If YES, what was their reaction?
    ....

25. For the farming decisions below, what information do you require/use (remember that the information would need to be available *before* your decision takes place)

Amount of land prepared					
Crop planting dates					
Crop selection					
Cultivar selection					
Fertiliser purchases					
Irrigation planning					
Stocking rate					

Borrowing money					
Other ………… …….					

26. In which month(s) do you normally make a planting (crop and date) decision (depending on rain)?

Before August	**August**	**September**	**October**	**After October**

27. How does other available information affect your planting decision?

	Definitely	***Lesser degree***	**Not at all**	**Is the info reliable?**	
				YES	**NO**
Maizevision					
Media					
Co-op					
Ag Extension					
Farmer group/association					
Other………………… …………………………					

28. When your crops fail or your yield is very low, do you believe that you are being punished by a higher Power?
YES □ **NO** □

29. With specific reference to the seasonal forecasts that you received, do you have any suggestions for improvement, changes or general comments for the producers of the forecasts?

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

30. How much information (about weather) do you require?

Much more	More	Enough	Less

31. DO you think you can make a better decision with more information?

Yes	No	Not sure

32. Do you think it is possible to assimilate and use all the information you receive?

Yes	No	Not sure

33. How do you feel about this statement? "*Less* information can actually be *more*"

Agree	Disagree	Not sure

34. Sources of Income 2003/4

Source	Types and detail	% of income
Crops		
Livestock		
Commercial business		
Other		

THANK YOU!

Appendix 4: Hedging Questionnaire - study group

HEDGING QUESTIONNAIRE - NOV 2004

Name: … ……………………………………

District: …………………………………...

The following questions concern your feelings and actions towards hedging. I would like to know whether you are considering it this season, if you have already invested, and if you are NOT considering it, why not. Please would you be so kind as to tick in the applicable space/block and post/e-mail or fax the form back to me. Many thanks

1. Planting: What percentage of your normal maize lands will you be planting this year

Much less	**Less**	**The same**	**More**	**Much more**	**Not sure**
………….	………	……….	……	…………	……..

2. Will you planting more of another crop(s) instead of maize? **Yes ….. No…..**

   Crops:……………………………………………………………..

3. Based on the forecasts and your experience, what do you expect this season

   a. In terms of **crop yield**?

Less than normal	Normal	More than normal
………………….	……….	………………..

   b. In terms of **price** (R/ton)? (say, May's price)

<900	900-1000	1000-1100	1100-1200	>1200
…..	……	……	……..	……

   c. In terms of **profit** for 2004/5

Less than average	Average	More than average
…………….	…………	………..

4. Are you considering hedging on SAFEX this season? Please circle a YES or NO option and fill in details if applicable.

YES: I have already bought ……………. ***Puts ………*** ***Calls ……..***

YES: I am considering buying ………… ***Puts ………*** ***Calls ……..***

NO: Based on my previous experience of….. ***Puts ………*** ***Calls ……..***

NO: I have never hedged and never will.

5. If you hedged last year…….,

   a. Did you buy ***PUTS ………***or ***CALLS……..***?

   b. At what price? ***PUTS*** …………………………
   CALLS ………………………….

   c. How did it work out for you?

Good profit	Small profit	Broke even	Small loss	Big loss
………..	…………	…….	……….	……..

   d. What do you think was the reason for this result?

Luck	Skill	Knowledge	Emotion
……	………	………	……

6. If you hedged last year, how did it affect your decision in terms of hedging this year?

………..…………………………………………………………………………

…………………………………………………………………………………….

……………………………………………………………………………………

THANK YOU VERY MUCH!

Peter Johnston
Fax: 021-6505773
Email: peter @egs.uct.ac.za

Optional info:

E-mail address: ……………………………………………………..

Tel number: ………………………………………………….

References

Adams, RM, Bryant KJ McCarl BA, Legler DM, O'Brien JJ, Solow A, Weiher R (1995) Value of improved long range weather information Contemp Econ Pol. 13(1995):10-19

Agrawala S, Broad K (2002) Technology transfer perspectives on climate forecast applications, in: Laet MD (ed) Research in science and technology studies: Knowledge and Technology Transfer 13:45-69

Agricultural Production Systems Research Unit (APSRU) (2003) http://www.apsru.gov.au /apsru/Products/Whopper/whatis.htm

Archer ERM (2003) Identifying underserved end-user groups in the provision of climate information. Bull Am Meteorol Soc 84:11

Arndt C, Bacou M (2000) Economy wide effects of Climate variability and climate prediction in Mozambique. A Journal of Agr Econ 82:750-754

Arndt C, Hazell P, Robinson S (2000) Economic value of climate forecasts for agricultural systems in Africa, in: Sivakumar MVK (ed) Climate prediction and agriculture. Proc START/WMO Int Workshop, Geneva, Switzerland, 27–29 September 1999. International START Secretariat, Washington, DC, 157–180

Australian Bureau of Meteorology (2003) www.bom.gov. au/climate/enso/#impacts

Barnston AG (2005) Improving seasonal prediction practices through attribution of climate variability. Bull Am Meteorol Soc 86:59-72

Barnston AG, Glantz MH, He Y (1999) Predictive skill of statistical and dynamical climate models in forecasts of SST during the 1997–98 El Niño episodes and the 1998 La Niña onset. Bull Am Meteorol Soc 80:217–244

Basher R, Clark C, Dilley M, Harrison MSJ (eds) (2001) Coping with climate: a way forward – summary and proposals for action; preparatory report and full workshop report, both published by the International Research Institute for Climate Prediction on behalf of the World Meteorological Organisation, NOAA, the South African Weather Bureau, USAID and the World Bank.

Bert F, Satorre EH, Toranzo F, Podestá G (2006) Climatic information and decision-making in maize crop production systems of the Argentinean Pampas, Agric Syst 88:180–204

Bezuidenhout CN (2001) Proposed framework for operational crop forecasts in the South African sugar industry. Proc S Afr Sug Technol Ass Congress, Durban 75:215–216

Bezuidenhout CN, Singels A (2001) The use of simulation crop modelling to forecast sugarcane yield. Proceedings of the SASTA workshop on burn/harvest to crush delays and crop estimating. Mt Edgecombe, South Africa, 20–29

Blench R (1999) Seasonal climatic forecasting: Who can use it and how should it be disseminated? Natural Resource Perspectives 47, Overseas Development Institute, London. www.oneworld.org/odi/nip/47.html

Bohn L (2003) Climate forecasts in Swaziland: perspectives from agribusiness, in: O'Brien KL and Vogel C (eds) Coping with climate variability: the use of seasonal climate forecasts in southern Africa. Ashgate, Aldershot 97–109

Broad K, Pfaff ASP, Glantz MH (2002) Effective and equitable dissemination of seasonal-to-interannual climate forecasts: policy implications from the Peruvian fishery during El Niño 1997-98. Climatic Change 54(4):415-438

Cane M (2000) Understanding and predicting the world's climate system, in: Hammer GL, Nicholls N, Mitchell C (eds) Applications of seasonal climate forecasting in agricultural and natural ecosystems: the Australian experience. Kluwer Academic Publishers, Dordrecht, 29–50

Cane MA, Arkin PA (2000) Current capabilities in long-term weather forecasting for agricultural purposes, in: Sivakumar MVK (ed) Climate Prediction and Agriculture: Proceedings of an International Workshop. International START Secretariat

Carberry P, Hammer GL, Meinke H and Bange M (2000), in: Hammer GL, Nicholls N, Mitchell C (eds) Applications of seasonal climate forecasting in agriculture and natural ecosystems: the Australian experience. Kluwer Academic Publishers, Dordrecht, 167-181.

Carter JO, Hall WB, Brook KD, McKeon GM, Day KA and Paull CJ (2000), in: Hammer GL, Nicholls N, Mitchell C (eds.) Applications of seasonal climate forecasting in agriculture and natural ecosystems: The Australian experience. Kluwer Academic Publishers, Dordrecht, 329-350

Cash DW, Buizer J (2005) Knowledge-action systems for seasonal to interannual climate forecasting. Summary of a workshop. Report to the Roundtable on Science and Technology for Sustainability, Policy and Global Affairs. The National Academies Press, Washington, DC

Cash D, Clark W, Alcock F, Dickson N, Eckley N, Jäger J (2002) Salience, credibility, legitimacy and boundaries: linking research, assessment and decision making. KSG Working Papers Series RWP02-046

Chapman SC, Imray R, Hammer GL (2000), in: Hammer GL, Nicholls N, Mitchell C (eds) Applications of seasonal climate forecasting in agriculture and natural ecosystems: The Australian experience. Kluwer Academic Publishers, Dordrecht, 367-380

Climate Systems Analysis Group, University of Cape Town (2001)www.csag.uct.ac.za and www.myweather.co.za

Coetsee J (2006) Nuwe 'Donker Eeue' voor die deur? Landbouweekblad 6 January 2006 http://www.landbou.com/LandbouWeekblad/Weer/0,,1294-1564_1859171,00.html

Daly JJ (1994) 'Wet as a shag, dry as a bone.' Drought in a variable climate. Queensland Department of Primary Industries, Brisbane

Dilley M (2000) Reducing vulnerability to climate variability in Southern Africa: the growing role of climate information. Clim Change 45:63–73

Doblas-Reyes FJ, Hagedorn R, Palmer TN (2006) Developments in dynamical seasonal forecasting relevant to agricultural management. Clim Res 33:19-26

Du Toit W (1999) Production of maize in the summer rainfall area. Agricultural Research Council – Grain Crops Institute. Pretoria, South Africa

Easterling WE, Mjelde JW (1987) Importance of seasonal climate prediction lead time in agricultural decision-making. Agri Forest Meteor 40(1):37-50

Einhorn HJ, Hogarth RM (1988) Behavioral decision theory: Processes of judgement and choice, in: Bell DE, Raffia H, Teversky A (eds) Decision making: descriptive normative and prescriptive interactions, Cambridge University Press

Everingham YL, Muchow RC, Stone RC, Inman-Bamber NG, Singels A, Bezuidenhout CN (2002) Enhanced risk management and decision-making capability across the sugarcane industry value chain based on seasonal climate forecasts. Agric Syst 74:459–477

Farago T, Wilhite DA, Glantz MH (1997) A forecast is just a forecast: it's not a guarantee. Int J African Studies (2), March 1997, University of Bradford: www.bradford.ac.uk/research/ ijas/ijasno2/farago.html

Festinger L (1957) Theory of cognitive dissonance. Row, Peterson, Evanston, IL

Fischhoff B (1994) What forecasts (seem to) mean. Int J Forecasting 10:387-403

Gettelman A (2003) The "information divide" in the climate sciences. Bull Am Meteorol Soc 84:1703–1709

Gigerenzer G, Hertwig R, van den Broek E, Fasolo B, Katsikopoulos KV (2005) "A 30% chance of rain tomorrow": How does the public understand probabilistic weather forecasts? Risk Analysis 25:623-629

Global Forecasting Centre for Southern Africa (2004) www.gfcsa.net

Goddard L, Graham NE (1999) The importance of the Indian Ocean for simulating rainfall anomalies over eastern and southern Africa. J Geophys Res 104:19099–19116

Goddard L, Mason SJ, Zebiak SE, Robelewski CF, Basher R, Cane MA (2001) Current approaches to seasonal to interannual climate predictions. Int J Climatol 21:1111–1152

Greenfield RS, Fisher GM (2003) Improving responses to climate predictions: an introduction. Bull Am Meteorol Soc, 84:1685–1685

Hallstrom DG, Sumner DA (2000) Agricultural economic responses to forecasted climate variation: crop diversification, storage and trade. International Forum on Climate Prediction, Agriculture, and Development, Palisades, New York

Hammer GL (2000) A general systems approach to applying seasonal climate forecasts, in: Hammer GL, Nicholls N, Mitchell C (eds) Applications of seasonal climate forecasting in agriculture and natural ecosystems: The Australian experience. Kluwer Academic Publishers, Dordrecht, 51-66

Hammer GL, Hansen JW, Phillips JG, Mjelde JW, Hill H, Love A, Potgieter A (2001) Advances in application of climate prediction in agriculture. Agric Syst 70:515–553

Hammer GL, Holzworth DP, Stone RC (1996) The value of skill in seasonal climate forecasting to wheat crop management in north-eastern Australia. Aust J Agric Res 47:717–737

Hansen JW (2002) Realising the potential benefits of climate prediction to agriculture: issues, approaches, challenges. Agric Syst 74:309-330

Harmon-Jones E, Mills J (1999) Cognitive Dissonance: Progress on a pivotal theory in social psychology. American Psychological Association, Washington, DC

Harrison M (2005) The development of seasonal and inter-annual climate forecasting. Climatic Change 70: 201-220

Hartmann HC, Bales R, Sorooshian S (2002) Weather, Climate and Hydrologic Forecasting for the US Southwest: A Survey. Clim Res 21(3):239-258

Henderson-Sellers A (1998) Climate whispers: media communication about climate change, Climatic Change 40: 421-456

Hoffman J (2004) A farmer's view of the human constraints to the adoption of seasonal climate forecasting in Australia, in: Huda AKS, Packham RG (eds) Using seasonal climate forecasting in agriculture: a participatory decision-making approach. Australian Centre for International Agricultural Research, Canberra 31-34

Huda AKS, Packham RG (eds) (2004) Using seasonal climate forecasting in agriculture: a participatory decision-making approach. Australian Centre for International Agricultural Research, Canberra 46-48

Hudson J, Vogel C (2003) The use of seasonal forecasts by livestock farmers in South Africa, in: O'Brien K, Vogel C (eds) Coping with climate variability: the use of seasonal forecasts in Southern Africa. Ashgate, Aldershot, 75–96

Ingram KT, Roncoli MC, Kirshen PH (2002) Opportunities and constraints for farmers of west Africa to use seasonal forecasts with Burkina Faso as a case study. Agric Syst 74:331-349

Johnston PA (2004) Tailored seasonal climate forecasts: opportunities and challenges for South African maize producers. Paper presented at AAG conference March 2004, Philadelphia

Johnston PA, Archer ERM, Vogel CH, Bezuidenhout CN, Tennant WJ, Kuschke R (2004) Review of seasonal forecasting in South Africa: producer to end-user. Clim Res 28(1):67-82

Johnston PA, Ziervogel G, Matthew M (2007) The uptake and usefulness of weather and climate information among water resource managers. Papers Appl Geog Conf 30:380-389

Jolliffe IT, Stephenson DB (2003) Forecast verification: a practitioner's guide in atmospheric science. Wiley and Sons, Chichester

Jones JW, Hansen JW, Royce FS, Messina CD (2000) Potential benefits of climate forecasting to agriculture. Agric Ecosyst Environ 82:169–184

Katz RW, Murphy AH (eds) (1997) Economic Value of Weather and Climate Forecasts. Cambridge University Press, Cambridge

Kgakatsi IB (2001) Exposing the benefits of weather and climate information to rural communities/subsistence farmers and dissemination in South Africa. In proceedings of communication of climate forecast information workshop. June 6-8 2001. Palisades NY: IRI for Climate Prediction

Klopper E (1999) The use of seasonal forecasts in South Africa during the 1997/98 rainfall season. Water SA 25:311–316

Klopper E (2002) The impact of weather on the economy. Paper presented at SASAS August 2002 Pretoria

Klopper E, Bartman AG (2002) Forecasts and commercial agriculture: a survey of user needs in South Africa, in: O'Brien K, Vogel HC (eds) Coping with climate variability: the use of seasonal forecasts in Southern Africa. Ashgate, Aldershot, 170–182

Klopper E, Landman WA (2003) A simple approach for combining seasonal forecasts for southern Africa. Meteorol Appl 10: 319-327

Klopper E, Vogel CH, Landman WA (2006) Seasonal climate forecasts – potential agricultural-risk management tools? Climatic Change 76:73-90

Krzysztofowicz R (1993) Strength of preference and risk attitude in utility measurement. Organizational Behavior and Human Performance, 31(1983):88-113

Landman WA (in press) ENSO and multi-model forecast skill for mid-summer rainfall over South Africa. Int J Climatol

Landman WA, Mason SJ (1999) Operational long-lead prediction of South African rainfall using canonical correlation analysis. Int J Climatol 19:1073–1090

Landman WA, Mason SJ, Tyson PD, Tennant WJ (2001) Retroactive skill of multi-tiered forecasts of summer rainfall over southern Africa. Int J Climatol 21:1–19

Landman WA, Tennant WJ (2000) Statistical downscaling of monthly forecasts. Int J Climatol 20:1521–1532

Lemos M, Dilling L (2007) Equity in forecasting climate: can science save the world's poor? Science and Public Policy 34(2):109-116

Lemos M, Finan T, Fox R, Nelson D, Tucker J (2002) The use of seasonal climate forecasting in policymaking: lessons from NE Brazil, Climatic Change 55: 479-507

Lindesay JA (1988) South African rainfall, the southern oscillation and a southern hemisphere semi-annual cycle. J Clim 8:17–30

Lindesay JA, Vogel CH (1990) Historical evidence for southern oscillation - Southern African rainfall relationships. Int J Climatol 10:679–689

Livezey RE (1990) Variability of skill of long-range forecasts and implications for their use and value. Bull Am Meteorol Soc 71:3:300-309

Lumsden TG, Schulze RE, Lecler NL, Schmidt EJ (2000) Assessing the potential for improved sugarcane yield forecasting using seasonal rainfall forecasts and crop yield models. Proc S African Sug Technol Assoc Congress, Durban 72:131-139

Maize Vision (2002) No 39, May 2003. http://www.ev.co.za/ev_maize.php?lang=EN

Maize Vision (2003) No. 46, June 2003. http://www.ev.co.za/ev_maize.php?lang=EN

Manning M (2003) The difficulty in communicating uncertainty. Climatic Change 61: 9-16

March, JG (1988) Bounded rationality, ambiguity and the engineering of choice, in: Bell DE, Raffia H, Teversky A (eds) Decision making: descriptive normative and prescriptive interactions. Cambridge University Press, New York

Martin RV, Washington R, Downing TE (2000) Seasonal maize forecasting for SA and Zimbabwe derived from an agroclimatological model. J of App Met 39:1473-1479

Mason IB (1982) A model for assessment of weather forecasts. Aust Meteorol Mag 30:291–303

Mason IB (2003) Binary events, in: Jolliffe IT, Stephenson DB (eds) Forecast verification. A practioner's guide in atmospheric science. Wiley and Sons Ltd, 37-76

Mason SJ (1995) Sea-surface temperature - South African rainfall associations, 1910–1989. Int J Climatol 15:119–135

Mason SJ (2000) Definition of technical terms in forecast verification and examples of forecast verification scores. International Research Institute Outreach Publication, Palisades, New York

Mason SJ, Goddard L (2001) Probabilistic precipitation anomalies associated with ENSO. Bull Am Meteorol Soc 82: 619–638 IRI website: http://iridl.ldeo.columbia.edu/SOURCES/.IRI/.Analyses/.ENSO-RP/.0p 5deg

Mason SJ, Goddard L, Graham NE, Yulaeva E, Sun L, Arkin PA (1999) The IRI seasonal climate prediction system and the 1997/98 El Niño event. Bull Am Meteorol Soc 80: 1853–1873

Mason SJ, Mimmack GM (1992) The use of bootstrap correlation coefficients in climatology. Theor Appl Climatol 45: 229–233

McGlinchey MG (1999) Computer crop model applications: developments in Swaziland. Proc S Afr Technol Ass Congress, Durban 73: 35–38

Meinke H, Hammer G (2000) Proceedings of the international forum on climate prediction, agriculture and development. International Research Institute for Climate Prediction, Palisades, New York

Meinke H, Pollock K, Hammer GL, Wang E, Stone RC, Potgieter A, Howden M (2001) Understanding climate variability to improve agricultural decision making.

Proceedings of the Australian agronomy conference. Australian Society of Agronomy

Meinke H, Nelson R, Kokic P, Stone R, Selvaraju R, Baethgen W (2006) Actionable climate knowledge: from analysis to synthesis. Clim Res 33:101-110

Mjelde JW, Hill HSJ, Griffiths JF (1998) A review of current evidence on climate forecasts and their economic effects in agriculture. Amer J of Agro Econ 80, 5 1089-95

Mjelde JW, Penson JB, Nixon CJ (2000) Dynamic aspects of the Impact of use of perfect climate forecasts in the corn belt region. J Appl Meteor 39:67-79

Msangi S, Rosegrant MW, You L (2006) Ex post assessment methods of climate forecast impacts. Clim Res 33:67-79

Murphy AH (1997) Forecast verification, in: Katz RW, Murphy AH (eds) The economic value of weather and climate forecasts. Cambridge University Press, Cambridge

Murphy SJ, Washington R, Downing TE, Martin RV, Ziervogel G, Preston A, Todd M, Butterfield R, Briden J (2001) Seasonal Forecasting for climate hazards: prospects and responses. Natural hazards 23:171-196

Nicholls N (1999) Cognitive illusions, heuristics, and climate prediction. Bull Am Meteorol Soc 80:1135-1397

Nicholls N (2000) Opportunities to improve the use of seasonal climate forecasts, in: Hammer GL, Nicholls N, Mitchell C (eds) Applications of seasonal climate forecasting in agriculture and natural ecosystems; the Australian experience. Kluwer Academic Publishers, Dordrecht, 309–328

O'Brien KL, Sygna L, Næss LO, Kingamkono R, Hochobeb B (2000) Is information enough? User responses to seasonal climate forecasts in Southern Africa Report no 2000-03 CICERO University of Oslo, Norway

Orlove BS, Broad K, Petty AM (2004) Factors that influence the use of climate forecasts. Bull Am Meteorol Soc 85: 1735-1743

Pagano TC, Hartmann HC, Sorooshian S, Bales RC (1999) Advances in seasonal forecasting for water management in Arizona: A case study of the 1997-98 El Niño. Department of Water Resources, University of Arizona

Pagano TC, Hartmann HC, Sorooshian S (2001) Using climate forecasts for water management: Arizona and the 1997-1998 El Niño. J Amer Water Res Assoc 37(5):1139-1154.

Palmer TN, Anderson DLT (1994) The prospects for seasonal forecasting. Q J R Meteorol Soc 120:755–793

Patt AG, Gwata C (2002) Effective seasonal climate forecast applications – examining constraints for subsistence farmers in Zimbabwe. Global Env Change 12:185-195

Patt AG, Schrag DP (2003) Using specific language to describe risk and probability. Climatic Change 61:17-30

Patt AG, Suarez P, Gwata C (2005) Effects of seasonal climate forecasts and participatory workshops among subsistence farmers in Zimbabwe. Proc Nat Acad Sci 102(35):12623-12628

Petersen EH, Fraser RW (2001) An assessment of the value of seasonal forecasting technology for Western Australian farmers. Agr Syst 70:259-274

Phillips JG (2003) Determinants of forecast use among communal farmers in Zimbabwe, in: O'Brien K, Vogel C (eds) Coping with climate variability: the use of seasonal climate forecasts in southern Africa. Ashgate, Aldershot, 110–128

Phillips JG, Deane D, Unganai L, Chimeli A (2002) Implications of farm level response to seasonal climate forecast for aggregate grain production in Zimbabwe. Agric Syst 74:331-369

Plant S (2000) The relevance of seasonal climate forecasting to a rural producer, in: Hammer GL, Nicholls N, Mitchell C (eds) Applications of seasonal climate forecasting in agriculture and natural ecosystems: the Australian experience. Kluwer Academic Publishers, Dordrecht, 23–28

Podestá G, Letson D, Messina C, Royce F, Ferreya RA, Jones JW, Hansen JW, Llovet I, Grondona M, O'Brien JJ (2002) Use of ENSO–related climate information in agricultural decision making in Argentina: a pilot experience. Agric Syst 74:371-393

Reason CJ, Mulenga H (1999) Relationships between South African rainfall and SST anomalies in the southwestern Indian Ocean. Int J Climatol 19:1651–1673

Richard Y, Trzaska S, Rocou P, Roualt M (2000) Modification of the southern African rainfall variability/ENSO relationship since the late 1960s. Clim Dyn 16:883–895

Roncoli C (2006) Ethnographic and participatory approaches to research on farmers' responses to climate predictions. Clim Res 33:81-99

Ropelewski CF, Halpert MS (1987) Global and regional scale precipitation patterns associated with the El Niño Southern Oscillation. Mon Weather Rev 115:1606–1626

Ropelewski CF, Halpert MS (1989) Precipitation patterns associated with the high index phase of the Southern Oscillation. J Clim 2:268–284

Ropelewski CF, Halpert MS (1996) Quantifying Southern Oscillation-precipitation relationships. J Clim 9:1043–1059

Rosenzweig C (2000) Impacts of the El Niño-southern oscillation on agriculture: guidelines for regional analysis, in: Rosenzweig C, Boote KJ, Hollinger S, Iglesias A, Phillips J (eds) Impacts of El Niño and climate variability on agriculture. ASA Special Publication 63, American Society of Agronomy, Madison, 21–30

Rubas DJ, Hill HSJ, Mjelde JW (2006) Economics and climate applications: exploring the frontier. Clim Res 33:43-54

SADC-DMC (2002) Report of the 6th Southern Africa regional climate outlook forum. Harare, 4–6 September 2002. SADC Drought Monitoring Centre, Harare

Schwarz B (2004) The Paradox of Choice – why more is less. Harper Collins, New York

Sherrick BJ, Sonka ST, Lamb PJ, Mazzocco MA (2000) Decision-maker expectations and the value of climate prediction information: conceptual considerations and preliminary evidence. Meteorol Appl 7: 377-386

Simon HA (1956) Models of Bounded Rationality. Volume 1, Economic Analysis and Public Policy, Cambridge, Mass., MIT Press, 235-44

Singels A, Bezuidenhout CN (1999) The relationship between ENSO and rainfall and yield in the South African sugar industry. S Afr J Plant Soil 16(2):96–101

Singels A, Donaldson RA (2000) A simple model for unstressed sugarcane canopy development. Proc S Afr Sugar Technol Ass Congress, Durban 74:151–154

Sivakumar MVK (2006) Climate prediction and agriculture: current status and future challenges. Clim Res 33:3-17

South Africa Online (2004) http://www.southafrica.co.za/agriculture_29.html

South African National Department of Agriculture (2003) www.agis.agric.za

South African Weather Service (SAWS) (2002-5) www.weathersa.co.za

Stainforth DA, Allen MR, Tredger ER, Smith LA (2007) Confidence, uncertainty and decision-support relevance in climate predictions. Phil. Trans. R. Soc. A 365:2145–2161

Stainforth DA, Downing TE, Washington R, Lopez A, New, M (2007) Issues in the interpretation of climate model ensembles to inform decisions. Phil. Trans. R. Soc. A 365:2163–2177

Standard Bank Agri-review (2005) www.stanbic.com/vgn/images/portal/cit_4931/27/39/14968741Agri_Eng2nd Quarter2005.pdf

Stanski HR, Wilson LJ, Burrows WR (1989) Survey of common verification methods in meteorology. World Weather Watch Tech Rept No 8, WMO/TD No 358, WMO, Geneva

Stern PC, Easterling WE (eds) (1999) Making climate forecasts matter. National Academy Press, Washington, DC

Stone RC, Meinke H (2005) Operational seasonal forecasting of crop performance. Philosophical Transactions of the Royal Society 360(1463): 2109-2124.

Stone RC, Meinke H (2006) Weather, climate, and farmers: an overview. Meteorol Appl 13: 7-20

Suarez P, Patt AG (2004) Cognition, caution and credibility: the risks of climate forecast application. Risk, Decision and Policy 9(1):75-89

Sugi M, Kawamura R, Sato N (1997) A study of SST-forced variability and potential predictability of seasonal mean fields using the JMA global model. J Meteor Soc Japan 75:717–736

Tapscott C (1997) Is a better forecast the answer to better food security? to better early warning? to better famine prevention? Internet journal of African studies (2): www.ccb.ucar.edu /ijas/ijasno2/tapscott.html

Tarhule A Lamb PJ (2003) Climate research and seasonal forecasting for West Africans: Perceptions, Dissemination and Use? Bull Am Meteoroll Soc 84(12):1741-1759

Tennant WJ (1999) Numerical forecasting of monthly climate in southern Africa. Int J Climatol 19:1319–1336

Tennant WJ (2003) An assessment of intra-seasonal variability from 13-year GCM simulations. Mon Weather Rev 131:1975–1991

Thornton PK (2006) Ex ante impact assessment and seasonal climate forecasts: status and issues. Clim Res 33:55-65

Vogel C (2000) Usable science: an assessment of long-term seasonal forecasts among farmers in rural areas of South Africa. S Afr Geog J 82:107–16

Vogel C, O'Brien K (2003) Climate forecasts in southern Africa, in: O'Brien K, Vogel C (eds) Coping with climate variability: the use of seasonal forecasts in southern Africa. Ashgate, Aldershot, 75–96

Vogel C, O'Brien K (2006) Who can eat information? Examining the effectiveness of seasonal climate forecasts and regional climate-risk management strategies. Clim Res 33:111-122

Von Storch H, Navarra A (eds) (1995) Analysis of climate variability. Application of statistical techniques. Springer-Verlag, Berlin

Walker S, Mukhala E, van den Berg WJ, Manley CR (2001) Assessment of communication and use of climatic outlooks and development of scenarios to promote food security in the Free State Province of South Africa. Final report submitted to the Drought Monitoring Centre, Harare

Washington R, Downing TE (1999) Seasonal forecasting of African rainfall: prediction, responses and household food security. Geogr J 165:255–274

Webster M (2003) Communicating climate change uncertainty to policy makers and the public. Climatic Change 61:1-8

Wilby RL, Wigley TML (2000) Precipitation predictors for downscaling: observed and general circulation model relationships. Int J Climatol 20:641-661

Wilhite DA, Glantz MH (1985) Understanding the drought phenomenon: the role of definitions. Water International 10: 111-120

Ziervogel G (2002) Seasonal climate forecast applications: a case study of smallholder farmers in Lesotho, D Phil Thesis, Univ of Oxford

Ziervogel G (2004) Targeting seasonal climate forecasts for integration into household level decisions: the case of smallholder farmers in Lesotho. Geogr J 170:6–21

Ziervogel G, Calder R (2003) Climate variability and rural livelihoods: assessing the impact of seasonal climate forecasts. Area 35(4):403–417